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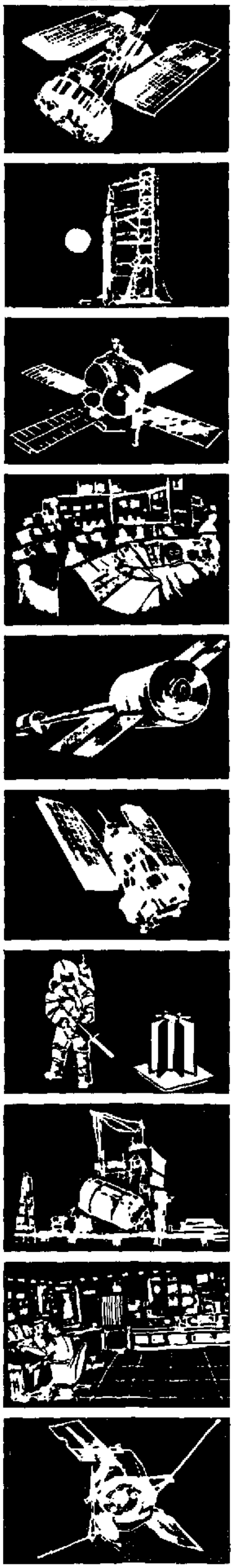

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EARTH OBSERVATORY SATELLITE SYSTEM DEFINITION STUDY

Report No. 4

LOW COST MANAGEMENT APPROACH AND RECOMMENDATIONS

EARTH OBSERVATORY SATELLITE

GENERAL ELECTRIC

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EARTH OBSERVATORY SATELLITE SYSTEM DEFINITION STUDY

Report No. 4

LOW COST MANAGEMENT APPROACH AND RECOMMENDATIONS

Prepared for:
GODDARD SPACE FLIGHT CENTER
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Under
Contract No. NAS 5-20518

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SECTION 1.0

INTRODUCTION AND SUMMARY

This report, "Management Approach Recommendations," has been prepared for NASA/GSFC under contract NAS 5-20518, EOS System Definition Study. It presents the results of the study conducted on Low Cost Management Approaches and recommends approaches which should be applied to the EOS Program.

The GE Space Division fully concurs with NASA's increasing emphasis on improving the cost effectiveness of space applications programs and has applied to this study the programmatic experience of ten years of earth observation applications.

Aerospace programs historically have been high cost programs and reasonably so. With extreme emphasis on highly reliable, redundant systems operating in a hostile environment and more often than not pushing new technologies, the hardware has been relatively high cost. This is not meant to imply unnecessary cost or waste. What is implied, is that highly sophisticated products of extreme technical complexity with high reliability of operation have been high in cost. As the aerospace industry expanded and matured, the "exotic" became commonplace, the hostile environment was found to be not too troublesome, and complexity and high reliability became almost routine. With these changes came concommitant cost reductions in the product primarily engendered by reduced sophistication and more economical methods of development, fabrication and test.

The EOS Program as configured by NASA provides an opportunity to look at the elements of cost commonly labelled "Management," to determine if there is a better, more economical way of doing business to further reduce the ultimate program life cost. The cost reduction trend has been evident in the aerospace industry for several years but has been primarily directed toward the traditional cost improvement approach. In order to dvelop a true low cost approach, the factors which cause cost to be incurred must be identified. What are the factors which drive up cost - the so-called cost drivers? Before we can determine the value and necessity of a cost, the driver for that cost must be identified and evaluated. In the study, the process of identifying and evaluating "cost drivers" soon indicated to the study team that the best approach to "low cost" is good, sound business management practices by both NASA and Industry.

As in commercial businesses, this approach has lowered costs and will reduce the cost of aerospace products. To lower costs means to cut out the "fat," minimize inefficiencies, and simplify. Cutting out the "fat" will result in the elimination of longer necessary requirements, providing only "meet" performance not "exceeds," unless cost and "modus operandi" are adjusted as a product matures. Minimizing inefficiencies means closely examining each function having cost associated with it, for necessity, size and timing.

In summary, low cost demands matching all requirements to expected performance, identifying reasonably risk for both NASA and Industry, establishing a cost, and managing to that "cost" by both parties. Lowest cost cannot be obtained unless both parties agree that cost is the number one driver to the final contract, in the requirements placed upon Industry, in sharing of the risk and in maintaining an efficient simple interrelationship.

In this study, several assumptions have been made:

- o "Business as usual" can be sufficiently defined to serve as a "benchmark" for showing "lower" cost in the techniques resulting from this study.
- o Reductions in NASA's "business as usual" requirements of any kind, e.g., technical or any other can be made if a lower cost can be shown and justified as not impairing the required performance or increasing the total program risk beyond acceptable levels.
- o A defined risk can be mutually agreed upon and jointly borne by both NASA and Industry, where experience says that the cost savings justifies the increased risk.

The key conclusions of this study are the following:

- o Systems and procedural controls currently imposed on the fledgling Aerospace industry should be relaxed on the now more mature Aerospace industry.
- o Commonality can significantly reduce hardware costs by allowing a multiple buy instead of single buy.

SECTION 2.0

OBJECTIVE

The objective of this study is to develop simplified management approaches which would lower the EOS Program cost from what it would be if these approaches were not implemented, i.e., NASA and Industry did "business as usual."

This low cost objective is not new or radical. Government/Industry enterprises have more often than not been the objective of cost reduction programs. What is new, is that in EOS NASA offers a timely systematic study to low cost management that will design more simplified techniques into the basic program structure to eliminate the "cost drivers" which create the higher cost of doing "business as usual." The study, therefore, was conducted so as to produce specific recommendations for cost effective management of the Execution phase of the EOS Program.

It must be pointed out, however, that the specific recommendations to be made in some instances would reduce the quality or performance of the hardware but only to levels that would be acceptable for the EOS Program.

It must be pointed out, however, that the specific recommendations to be made in some instances would reduce the quality of performance of the hardware but only to levels that would be acceptable for the EOS Program.

It is not an objective of this study to analyze and describe how industry can perform internally at a lower cost, but to identify and define Industry/NASA interfaces that would produce a lower EOS-A Program cost than if implemented on a "business as usual" interface. Therefore the study is directed at the NASA/Industry interface and how that interface can be improved so that NASA and Industry's internal implementation can, as a result, be streamlined and made more cost effective.

SECTION 3.0
STUDY APPROACH

The first step taken by GE in this task of the EOS study was to identify the "cost drivers" associated with "business as usual" that might be subject to a lower cost effect based upon history or maturity; inefficiencies that have crept in through continual use; any uniqueness, such as modular subsystems/multiple buy, of EOS, and any unnecessary requirements.

Secondly, the study team then investigated the larger cost element of any space program to determine methods or approaches that might still satisfy requirements but cost less.

And finally, the study team analyzed those specific management approaches that could reasonably be implemented by NASA and industry in time to benefit the EOS-A Program with complete justification that neither performance nor risk would change from what NASA could expect under "business as usual" conditions.

Because all of these opproaches are so closely tied to contractual requirements, the study team focused on the analysis of the value of NASA management requirements in selected areas to identify those specified requirements which could reasonably be eliminated or modified with a resultant cost decrease but without adverse impact on the EOS Program. To establish the basic framework of the study task, an experienced team of senior GE management personnel was assembled to identify the management areas or techniques which in their judgement offered a good potential for cost reduction. The areas of analysis derived were:

- o Program management as regards NASA/Industry interface with particular attention to the degree of control of Industry by NASA.
- o Program documentation with a decided view towards reducing the paper flow.
- o Contracting techniques as regards the type of contract and the prime system contractor concept vs. associated contractor concepts.
- o Subcontracting techniques as relates to prime vs. associated contractor concepts.
- o Test philosophy with emphasis on the advisability of complete part, component, subsystem and system test.

- o Reliability and quality assurance requirement with a prime goal of elimination of duplication of effort, such as inspectors inspecting inspectors.

In addition to the identification of the foregoing cost areas, the following innovative concepts were recommended for investigation.

- o EOS commonality potentials.
- o The possible application of a "Design-to-Cost" philosophy and phased contracts.
- o The possible application of appropriate commercial practices to Aerospace contracts.
- o The possible contractual application of Value Management.

Each of the above areas is described in a separate section with a recommendation for or against implementaion on EOS and where possible a best estimate of possible cost savings over "business as usual."

SECTION 4.0
STUDY TASKS

4.1 PROGRAM MANAGEMENT

This portion of the study effort was concerned solely with interaction between NASA and industry in the areas of generalized program management and control, and data management. The question was asked, 'How best and most economically can NASA maintain the required control of industry while maintaining the orderly progression of effort?"

The NASA/Industry organization to provide overall management of the EOS Program consists of the necessary personnel to provide top-level program direction, planning and control; cost and schedule control; contract and subcontract administration and general administration. This cost has throughout the past years been deeply scrutinized and depressed to between 7 and 12% of the total program cost. The 5% spread is generally attributable to the type of program with a sequentially scheduled "off-the-shelf" program at the low end and a concurrent development/production program of "off-the-shelf" technology at the high end.

Commercial product businesses do not normally incur a program management cost of this magnitude. It is generally conceded that it costs less to run a commercial products business than it does to run a business whose products are sold to the Government because mangement has more freedom to take risks in commercial business.

This is both caused and explained by several factors. In the space business the product must work the first time; therefore, quality of the product is the number one cost driver while for a commercial product a warranty reserve is frequently established so that if the product breaks down it can be brought back for repair or replacement, consequently cost is the number one driver. The space product is a highly complex product and there are few products sold commercially which approach the complexity of space hardware. In addition, the aerospace business, along with all other businesses that sell to the government particularly on a cost-plus basis are subject to regulation and audit by the government whereas in a commercial business audits are conducted by company or company hired personnel. This ultimate responsibility to the taxpayer has caused the need for large complex data banks or filing systems not generally required in industrial or consumer product business. The follow-on market for spacecraft is usually very small when compared to commercial businesses, thereby requiring what are usually non-recurring costs to be written off against the one or two items produced. The small number of parts required limits the number of items which can be sold later. As a result there is no benefit of learning curves or volume production from which commercial products benefit. This list of criteria are summarized in Table 4-1.

The remainder of this section of the report will categorize cost control techniques used in commercial businesses for consideration on the EOS program. The categories to be described include:

- o Operations within NASA
- o NASA interfaces with the contractor

Table 4-1. Differences Between Commercial and Aerospace Business

Aerospace	Commercial
1. Performance is #1 price driver - cost is #2	Cost (profit) is #1 driver
2. Complex - highly technical product	Generally less technical, less complex
3. Highly regulated (ASPR's)	Minimum regulation
4. Limited quantity - highly customized	Medium to high production
5. Dual risk - Government and industry	Single risk - industry
6. Return on investment small for industry	High return on investment
7. Follow-on market small	Follow-on market may be large (spares, maintenance, repair)
8. Must work the first and only time	If it doesn't work - bring it back

- o Operation of the program by the contractor
- o Contractor interface with subcontractor

In each of these areas, ideas for cost control will be described and evaluated in terms of "payoff potential" and "risk. Since the EOS program is a large, complex spacecraft program, the Aircraft Engine Division (AED) and the General Electric Locomotive Products Department (LPD), both of which produce large complex products, were selected as a basis for study and comparison.

4.1.1 OPERATIONS WITHIN NASA

After considering the management techniques used in AED and LPD as typical well-managed commercial organizations, several techniques emerge for potential use by NASA management during the life of the EOS program, including:

- o Operating the program with tasks in series rather than in parallel.
- o Development of a standard product (General Purpose Spacecraft) and production of many of that product.
- o Minimize design refinement and correct mistakes at assembly or test where labor is cheaper.
- o Increase use of lower cost personnel.
- o Charge other organizations for doing work to accomplish their objectives.

<u>Operate as a "Series" Program</u>. In AED and LPD and in almost all well-run industrial organizations where a major concern is that the amount of money available for investment is limited, management conducts projects with steps toward completion in series rather than in parallel. This avoids having portions of the work being done more than one time because of inadequate definition or because of making decisions with incomplete information. This technique permits incremental funding of elements of the program which in turn enables management to evaluate ideas, results, personnel and organizations on the basis of work completed. Adjustments can then be made to market conditions (congressional to executive pressures), or changes in goals. The major disadvantage is that the program will run for a longer period of time, which in itself tends to increase cost, but results in less total expense.

Development of a Standard Product. An approach used successfully by industrial organizations to control costs is to standardize the product. This provides benefits in personnel becoming more efficient at their tasks during the life of the production run (learning curves), benefits to purchasing because quantity purchases often enable the buyer to obtain price breaks and increases the quality of later products by permitting time for problem solving on earlier products. Another advantage which NASA would gain is that cost increases resulting from inflationary pressures can be avoided by producing many of the standard products early. If necessary, modification kits can be prepared to add or subtract power, attitude control gas or other required element.

Push Costs Downstream. An operating philosophy in many successful commercial organizations is to minimize the design refinement activity and to solve design problems as close to shipment as possible. This tends to reduce costs by minimizing the need for the higher priced professional and semi-professional technical labor. An organization can use a great number of hours designing for worst case situations, making drawings in great detail, planning for all conceivable situations and too often most of the worst cases will not occur. The operating philosophy in commercial activities is to design and plan for the nominal situations and if something turns up as a problem in either manufacturing or test, solve the problem at that time.

Increase Use of Lower Skilled Personnel. By breaking tasks into finite pieces and by means of specialization, it is possible to make effective use of lower skilled personnel. Commercial businesses use this technique extensively. The benefits that accrue are that personnel are well trained, very experienced, relatively low cost, yet effective. They are relatively inflexible and usually will not step out of their specific area of responsibility. This, of course, puts more pressure on management when problems occur or when there are grey areas of responsibility between personnel.

These and other potentially adaptable techniques, their possible risks and payoffs are listed in Table 4-2.

Table 4-2. Techniques Used by Commercial Businesses Internally Which Could Be Considered For Use At NASA

Technique Possible	Potential Risk	Potential Payoff	Remarks
Operate program on series basis.	Lengthen program which could add to cost.	Less work being done over.	Highly recommended.
Purchase bus in high quantity.	Obsolescence of bus or extensive modifications.	Less expensive. Permit learning curve to be effective, improve quality.	Purchase 5 to 10 spacecraft new.
Push costs downstream	Lengthen time to solve problems.	Fewer technical people required, fewer draftsmen and technicians.	Very effective techniques in commercial business.
Increase use of lower level personnel.	Increases pressure on management, can lead to mistakes because of lack of experience. Not as much growth or movement of employees. Limited flexibility of people.	Lower cost to program.	In GE Locomotive Department 200,000,000 $/yr. business has only 350-400 exempt employees. Complex product much design effort.
Charge back to other agencies for meeting their goals, e.g., charge small business for administration effort.	Conflict between agencies and GAO.	Lower cost for NASA.	Obtain quote from contractor for each clause which requires additional effort.
Eliminate representatives living at contractor.	Loss of management (NASA) visibility.	Reduce overhead expenses, number of personnel office expenses, travel.	Locomotive Dept. at GE buys 100,000,000 $/yr. of supplier equipment - have no expediters living at any supplier plant.
Minimize formal planning for contingencies.	Depends on ability of management to recover when in trouble.	More time for management to work in technical areas. Less time required for administration of clerical personnel.	Could also increase the length of the program.

4.1.2 NASA INTERFACE WITH CONTRACTOR

All organizations can work to reduce costs internally with some degree of success, but to many organizations, where purchased material or services is a large part of cost it is also important to review procedures and methods used in dealing with suppliers. This section of the report deals with the relationship between commercial businesses and their suppliers to compare the methods they use with those normally used by NASA with their suppliers.

Some of the techniques used by commercial organizations to keep costs low on subcontracted or purchased items include:

- Detailed product development planning reduces costly change of scope and objectives
- Minimum trips, few expediters, no personnel living at supplier plant
- Minimum number of terms and conditions in contract
- Contract is usually written for total program
- Commercial organizations do not attempt to specify supplier internal procedures
- Do not use military or Government specifications
- Negotiate options for additional equipment
- Lease rather than purchase equipment

The risks and payoffs associated with the above ideas, and a few others, are listed in Table 4-3.

4.1.2.1 Reliance on Supplier Technical Expertise

Large commercial organizations rarely design a complex element of their final product. They usually find it more inexpensive to depend on the specialty companies where the technical expertise is available rather than hire those people for their own organization. If supplier companies are sufficiently competent in their fields so that there are few unknown situations, they generally prefer fixed price contracts. In addition, their expertise minimizes delivery delay risks. Commercial organizations do, however,

Table 4-3. Techniques Used By Commercial Business With Their Suppliers Which Can Be Considered By NASA

TECHNIQUES POSSIBLE	POTENTIAL RISK	POTENTIAL PAYOFF	REMARKS
Increase reliance on technical expertise of contractor.	Schedule risk if problems develop which require NASA help.	Less NASA internal cost.	Must select capable, technically honest supplier.
Eliminate representatives living at suppliers.	Loss of management visibility.	Reduce overhead, expenses of technical personnel, office expenses and travel.	A commercial department within GE buying 100,000,000 $/year of supplier equipment. Has no expediters living at any supplier plant.
Reduce number and extent of contract terms and conditions.	Could have problems with GAO. May conflict with goals of other agencies.	Lower overhead, less people.	Requires special approvals within government.
Eliminate limitation of NASA obligation by period; contract or entire program.	Problem obtaining funding.	Lower administrative cost, less people, less record keeping.	Depends on budget authority.
Do not specify contractor internal procedures.	Loss of element of control and knowledge by NASA.	Lower cost, supplier can use his own routine procedures. Reduce OH and special costs.	Easily applied, minimum risk.
Eliminate use of program, Mil-specs.	Could cost more to prepare new specs.	Use commercial specs, lower OH, less certifications.	More pressure on knowledgeable spacecraft management people.
Negotiate options for additional equipment.	Cost of the option.	Lower end item cost for future equipment.	Could be impossible to negotiate because of inflation.
Lease rather than purchase equipment.	Conflict with other programs is possible.	Permit contractor to gain investment tax credit, to amortize equipment and gain income tax benefit which can be passed on to NASA.	Could be effective depending on supplier's willingness to accommodate and availability of investment funds.
Make no claim for subcontract patent or copyright rights.	Loss of future benefit.	Subcontractor can gain benefit and may be willing to reduce cost by taking risk.	Will require special approval within government.
Increases use of Government equipment.	Cost to determine where equipment exists may not be recoverable.	Reduced cost.	By reviewing army, AF, etc. available surplus and unused equipment lists.
Increase reliance on oral reports, less on written.	Historical records not available if something goes wrong.	Fewer technical personnel, typists, clerical and overhead people at both supplier and NASA.	Could file vugraphs, charts, rough notes and the like. Could use bound notebooks.
Build more design margin and do less sophisticated analysis and test.	More reliance on design.	Lessen analysis and test.	Must use judicious cost trades.
Increase willingness to take risks; e.g., less analysis (reliable)	More reliance on testing and repairs.	Fewer analyses, less technical personnel	Must use judiciously - it may be cheaper to analyze and not test.
Use fixed price contract for spacecraft after development.	Less information available.	Lower cost.	Should minimize NASA controls after development work complete.
Merge NASA personnel with contractor personnel.	Objectives of workers can be muddied.	Needs strong management to make it work.	Has been used by commercial organizations; "TACRV project for DOT" as an example.
Purchase a mockup to evaluate changes.	Cost of mockup and usefulness could be questioned.	Permits easy checking of configuration changes later in the program.	Used in aircraft development extensively.

utilize value engineering techniques to reduce the cost of the product once the design is underway. This technique, along with "design-to-cost" are extremely effective in the control of costs.

4.1.2.2 Trips, Expediters and Company Representatives

The Locomotive Products Department's sales are on the order of $200,000,000 per year, purchases to support these sales run about $ 100,000,000. Yet LPD uses very few expediters, permits very few trips for purposes of expediting and has no company representatives living at any supplier's plant. The Locomotive Products Department has only six expediters all of whom are non-exempt personnel. Almost all contacts are made by telephone. In fact, the travel budget for the entire purchasing unit in 1973 was on the order of $6-10,000. If this approach were adopted by NASA, a major risk would be the loss of management visibility.

4.1.2.3 Minimum Number of Terms and Conditions

Commercial organizations prepare contracts with a minimum of terms and conditions which tend to keep costs low. Comparing terms and conditions used commercially with those used in Government contracts indicates that several of the NASA standard terms and conditions have no parallel in commercial subcontracting.

There are many clauses recommended by the NASA Procurement Regulation Handbook for use in contracting usually not used in commercial applications, which tend to add cost - ref. Table 4-4. These are only representative samples. In place of these clauses, rules of law based on the "Commercial Code" are usually considered sufficient.

A question which must be answered is, "Is it possible to write a contract between the Government and a supplier without using the clauses above, either in part or totally "
It is believed that it is possible to reduce the optional clauses without increasing any risk to NASA.

Table 4-4, Examples of Non-Mandatory Clauses Used by NASA as Standard Operating Procedures

Clause		Effect
No.	Synopsis	
7.103-2	Changes The contracting officer may make changes to drawings, design, specs, method of packing or shipment and place of delivery. If change causes increase or decrease in cost, time, or performance, an equitable adjustment shall be made in price, delivery or both. Claims by contractor must be asserted within 30 days (may be changed to "not to exceed 60 days"). Failure to agree invokes "dispute" clause.	Contractor must be extremely alert to technical changes. In a large organization where the government has people in residence, with people constantly in contact and where contractor trains people to react favorably to customer personnel, it is difficult for management to learn of cost adding changes. Therefore, contingency fund must be larger.
7.103-3	Extras No payment for extras unless authorized in writing by the contracting officer.	May cause conflicts between technical personnel if contractor personnel refuse changes.
7.103-5	Inspection Supplies or lots which have been rejected or require to be corrected shall be removed or, if permitted or REQUIRED by the contracting officer, corrected in place by and at the expense of the contractor ...	The right of a unilateral decision has the tendency of adding risk for the contractor (which would rarely be accepted by a commercial organization) forcing him to add contingent costs. For example, the contractor may find it cheaper to repair the items in his own plant.
7.104.20(a) 7.203.26 7.302.26 7.402.27 7.702.35 7.703.27	Utilization of Concerns in Labor Surplus Area Contractor is required to consider labor surplus area subcontractor for award of subcontract over $500,000.	Additional solicitation for proposals, additional evaluation, record keeping, clerical increases, etc. Notify the subcontracting office of names of subcontractors.

4.1.2.4 Supplier Internal Procedures

The main interest of a commercial organization with his supplier is that the supplier provide a high quality part on schedule. It sometimes appears that a government agency is more interested in having the supplier follow a system rather than produce good hardware. Although the magnitude of this problem has been reduced in the past few years, there are still some vestiges of it remaining and when it exists, it adds to the cost of the program.

4.1.2.5 Use of Government and Military Specs

Government and Military Specifications have always had excellent details and are well written. The problem for commercial organizations is that they permit no cost saving shortcuts or time saving methods. They are very much oriented, as they should be, to getting an excellent product. As a result, the costs are high, and as a further result the price is high. Government Specifications should be carefully reviewed jointly by NASA and the system contractor to ascertain whether each "requirement" is really necessary for each particular program.

4.1.2.6 Options

When a commercial business makes purchases they often negotiate an option clause which obligates the supplier to produce an additional number of units for a fixed amount of money within a fixed time frame. This type of option may add to the original cost but the tradeoff can be evaluated when the parameters are known.

4.1.2.7 Lease Rather Than Purchase

Both commercial businesses and homeowners frequently find it cheaper to lease a piece of equipment rather than purchase it outright. This saves the costs of ownership, interest and maintenance. Most lease arrangements have a purchase break-even point dependent upon period of use. Whenever possible, lease versus purchase should be investigated.

Other organizations within NASA may have some usable equipment. NASA's G.C. Marshall Space Flight Center published in April of 72 a catalog of "ATM Ground Support Equipment" which was available as late as early 1974.

4.1.3 CONTRACTOR PROGRAM OPERATIONS

The amount of control NASA imposes on the contractor's operation poses a dilemma for NASA. If NASA imposes its desired operating approach on the supplier, it is possible that additional costs will result. On the other hand, if NASA adopts a "hands-off" attitude with respect to operating procedures they will be concerned whether the project is being completed in a high quality-expeditious manner. The best protection, of course, is to contract with a company which has a good reputation and applicable experience. There are many techniques which NASA can influence the contractor to use to minimize costs; including those indicated in Table 4-5. Most of these are used by commercial organizations within GE with some degree of success. Some of these will be similar or identical to the techniques shown in Tables 4-2 and 4-5.

The contractor can help reduce program costs by utilizing some of the following techniques:

- o Use a program "war" room and hold daily meetings
- o Use "Tiger" teams to attack high cost items
- o Increase use of lower level personnel
- o Push costs downstream by reducing number of technical personnel, checkers, and planners
- o Push costs downstream by reducing component testing
- o Increase search for subcontractors

4.1.3.1 Use of a Program "War" Room

A program "war" room is a room set aside for the mounting of chart-size schedules and action items. Responsible program personnel are required to keep the mounted schecules current. It is used by the program manager and his staff who conduct daily meetings in the room with responsible technical personnel. Each day one or more of these people are required to make a presentation on the status of their effort. As the presentation is made the program manager and his staff develop questions and action items which require response by appropriate program personnel. The use of such a room reduces costs by reducing the need for written communications along with the attendant typing and clerical functions, reduces the possibility that required work will "slip-through-the-cracks" and not

Table 4-5. Techniques Used by Commercial Departments within GE to Control Costs

IDEA	POTENTIAL RISK	POTENTIAL SAVING	REMARKS
Use of schedule "War Room" and daily meetings	Time expended in meetings.	Management visibility and control without formal reporting.	• Needs strong experience and management. • Accomplished only at highest levels in commercial work.
Special management "topic" review meetings	Management may concentrate on technical aspects rather than cost.	Management visibility into problems.	Should include financial reporting as in commercial business. Engineers should be responsible for costs.
Use "Tiger" team to reduce costs.	Additional effort may be required to assure that quality is not "cost reduced" out.	Value engineering approach to cost cutting.	Requires discipline. LPD (Locomotive Products) used this approach for 21 million in savings on $200,000,000 sales in 1973.
Increase use of lower level personnel.	Increase pressure on management.	Lower cost.	• Reduces people flexibility • Less upward mobility or sideways movement by employees • Restricts growth.
Push costs downstream, reduce number of checkers and planners.	Problems will show up in assembly.	Less personnel on program. Design and Planning personnel are more expensive than shop people.	• Tradeoff is - "Is it cheaper to find problem before assembly or fix at assembly?" • Most commercial organizations work to reduce upstream cost.
Push costs downstream, reduce component testing.	Problem will show up in system test.	Less personnel on program.	• Tradeoff is - "Is it cheaper to find problem before assembly or fix at assembly?" • Most commercial organizations work to reduce upstream cost.
Increase search for subcontractors.	May increase costs if difficult to find.	Reduced cost through added competition.	Commercial business goes far and wide to obtain competitive sources including foreign suppliers.

be completed, assures management attention, raises morale of the program personnel by assuring that their work has management attention and improves communication.

4.1.3.2 "Tiger" Team

Occasionally, a particularly difficult problem will be brought to management's attention which continues in a persistent manner to refuse to be solved. At times like this it is frequently useful to assign a group of specialists to solve the problem. The problem can either be technical or financial. The use of "tiger" teams relates back to the discussion of "Value Management" discussed in Section 4.9 of this report. The decision on using such an approach would be the responsibility of the program manager. The advantages would be to bring the best people to bear on problem solving in order to prevent a problem from holding up the entire program.

4.1.3.3 Increase Use of Lower Level Personnel

This discussion was covered in paragraph 4.1.1 of this report. As it applies to NASA it also applies to industry. In addition to those comments made in the earlier paragraph, it should be realized that a major difference in commercial business from the space business is the utilization of personnel. In a commercial business the ratio of non-exempt (lower level) people to exempt people is much higher. This requires that management be more specific in task definition because the lower level people, though usually extremely competent in a narrow job, cannot handle broad responsibilities. These people are usually much less flexible, much less likely to want upward mobility and are far more satisfied with routine.

4.1.3.4 Reduce Component Testing

Careful evaluation and tradeoff between component and subsystem versus system testing should be considered. Here again, by pushing as much of the cost downstream the total cost should tend to be lower. It is possible to design and test for all potentialities but to do so becomes an expensive exercise since most of the contingent situations will never happen. If they do not occur, the design and planning or component test effort is wasted. If problems occur they can be solved at that time so that no manpower is wasted. If the system test can be designed to exercise the component appropriately it should be possible to eliminate or minimize the component test.

4.1.3.5 <u>Increase Search for Subcontractors</u>

If the problem is faced properly, it should be possible for Purchasing to obtain more potential sources for commodities. By so doing, competition can be increased and Purchasing will then have better leverage to obtain lower prices.

4.1.4 CONTRACTOR INTERFACE WITH SUBCONTRACTOR

In a large project, an important part of the cost of doing business is usually associated with purchasing materials or services. Management, therefore, should be concerned with techniques, methods or systems which have the effect of reducing the cost of subcontracts. Since material and labor costs are fairly well established once a subcontractor understands what he is to produce, negotiation brings only limited reductions. Therefore, it is often fruitful to review operating procedures, communications techniques, reports, data requirements, certifications and other peripheral costs in order to be "cost effective".

Some techniques used by commercial businesses in managing subcontractors are:

- o Use of fixed price contracts
- o Increased reliance on oral reports, less on written
- o Elimination or marked reduction of trips to supplier plants
- o Increase quantity purchases early in program
- o Avoiding the specification of subcontractor internal procedures
- o Negotiating options for additional equipment
- o Purchase of parts and holding in supplies inventory without assembling until required
- o Contractor purchase of special equipment
- o Obtaining discounts for early payment

The potential payoff and risks for each of these ideas is summarized in Table 4-6.

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Table 4-6. Techniques Used by Commercial Organizations to Manage Subcontractors

ITEM	POTENTIAL RISK	POTENTIAL BENEFITS	REMARKS
Use of fixed price contract.	If financial problem occurs supplier may badly slip schedule. In commercial business cost breakdown isn't determinable when fixed price contract is used.	Known cost.	Must expect to pay higher fee from DOD report "Profit Rates on Negotiated Prime Contracts", 1964-1973 FFP 11.1% profit EPI 10.1% CPIF 7.7% CPFF 6.3%
Increase reliance on oral reports, less on written.	Problems may be hidden until too late to save schedule.	Less cost - less overhead and direct personnel.	Can use telephone for obtaining information. Request oral reports at supplier plant
Eliminate or markedly reduce trips to supplier plant.	Reduced management visibility.	Reduce travel and living expenses.	Use telephone for information. Use expediters.
Increase quantity purchase early in program.	Obsolescense because of design change. Cost of carrying inventory may be high.	Save on price breaks, inflationary pressures.	Quantities may be too low to gain benefit but this technique is used extensively by commercial organizations placing material in inventory.
Do not specify subcontractors internal procedures	Loss of management visibility.	Lower cost of OH.	On fixed price particularly risk is subcontractors.
Negotiate options for additional equipment	May not be possible because of inflationary pressure.	Assure spot in schedule and try to stabilize price.	Quantities may be too low.
Purchase parts and have supplier hold in inventory without assembling until required.	Obsolescence and cost of carrying inventory.	Assured availability of parts with no inflationary adders other than labor of assembly.	Used on occasion by commercial organizations - particularly to protect against potential labor strikes.
Contractor purchase special equipment and lease to sub.	May be more costly depending on who (contractor/ sub) is more capable financially.	Contractor gains investment tax credit and income tax benefit.	On occasion a commercial organization will purchase equipment and lease it to sub.
Obtain discounts for early payment.	Depends on interest rates and which company can make better use of money.	Discounted invoice can save up to 1%/month at the present time.	Only useful if subcontractor has receivable problem.

4.1.4.1 Use of Fixed Price Contracts

Of great importance is the type of subcontract. In a fixed price subcontract, for example, where the risk is greatest, the subcontractor usually quotes the highest profit because of his need for a contingency fund; in a cost plus contract on the hand, the contractor is usually satisfied with much lower fees. The commercial businesses use fixed price contracting almost exclusively. In fairness, however, it must be stated that the magnitude of risk is usually considerably less than that which would put the company in financial jeopardy while that is sometimes not the case with the smaller space hardware suppliers.

Fixed price contracts can be used most effectively when the design and production variables are known and when there is little concern over need for changes. If the program has the benefit of permitting fixing all or most requirements early, the fixed price subcontract would be most attractive.

4.1.4.2 Increased Reliance on Oral Reports

Written reports require typing, numbering, filing and maintenance of files. Cost control requires the prevention of adding personnel to the payroll. The subcontractor will have sufficient personnel available to accomplish some level of effort to prepare formal, written reports. Beyond that "given" level it will be necessary to add personnel. The contractor should make the effort to determine whether his requirements for formal reports forces the subcontractor to add personnel. If it does, the contractor could scale his requests down to eliminate the additional cost.

4.1.4.3 Trips to Supplier Plants

Trips to suppliers are expensive. For example, a two-day trip for one man from Philadelphia to Los Angeles would cost over four hundred dollars. It is easy to understand how a significant number of dollars can be saved by not making trips. In order to accomplish this, it may be necessary to raise the level of approval required to authorize trips. In addition, it will put additional pressure on telephone and other communication methods.

4.1.4.4 Increase Quantity Purchases Early

If the contract with NASA is for a sufficient number of general purpose spacecraft, an attempt should be made to maximize the number of components purchased from a single supplier. By this method it should be possible to interest additional suppliers in bidding for the work and to obtain price breaks for volume purchases. Purchases made early in the program will most likely be less expensive than if made later because increases due to inflation will be avoided. The main risk will be that the equipment purchased might not be usable later because of engineering changes. Also the cost of carrying the material in inventory, usually considered 20 - 30% of the value of the material, must be traded off against the potential saving.

4.1.4.5 Subcontractor Internal Procedures

The tendency for a contractor is to specify routines which work in his organization, for use by the subcontractor. Unfortunately, those procedures which work in one organization will not necessarily work in another. In addition it may be necessary to superimpose the new system on top of one already in existence which does nothing more than add cost. Although this practice is tending to be overcome with recent programs, there still remain some vestiges of the practice. In order to guard against the practice, all procedural specifications or requirements should be reviewed to question the necessity for their inclusion.

4.1.4.6 Negotiate Options for Additional Equipment

During the original negotiations, it may be possible for the contractor to obtain an option clause which would have the effect of binding the supplier to providing additional units at the same or only slightly increased cost. This kind of option will not, of course, be obtained without some cost to the contractor. Therefore, once again there is a tradeoff to be made. That is, the cost of the option against the potential saving.

4.1.4.7 Purchase Inventory to be Held Unassembled by the Supplier

In order to obtain the benefits of having additional parts, as protection against failures or as additional components for later spacecraft, without paying for the entire component, the contractor could buy elements and have the subcontractor store them. For example, if a particular component requires resistors, switches, relays, etc. which must be assembled into a black box, the contractor could have the subcontractor purchase all the elements and have them held in bonded stock until required without making the assembly. These elements will then be from the same lot of material so that requalification will not be necessary (depending on shelf life) and the contractor will not have to pay for assembly and test through G&A and profit. He will also gain the benefit of reduced schedule to complete the item should he decide later to complete the product.

4.1.4.8 Contractor Purchase Special Equipment

In order to minimize the cost to the program, and depending on which company has the most available funds and which has the greatest tax benefits resulting from such acquisition it may be better for the contractor to purchase special equipment for lease or loan to the subcontractor rather than have the subcontractor make the purchase.

4.1.4.9 Discounts for Early Payment

One technique used extensively by commercial businesses is the use of discounts to obtain early payment. It is to the benefit of the supplier to obtain cash quickly in order that he avoid borrowing at high interest rates. Therefore, discounts of 1% for payment within 30 days of tendering the invoice is quite common. Effort should be made to extend this practice which is not universal in the aerospace industry.

4.1.5 SUMMARY

The preceding sections contain many possible changes in management techniques and methods, all of which individually and collectively say that more reliance can now be placed on the capability of the Aerospace industry and, therefore, the tight contractor control that has developed over the past years can, in fact, be somewhat relaxed. Although it is not possible to quantize cost savings, intuitively it is apparent that some savings in program management costs will result if industry is provided less regimentation and adherence to rigid check and balance systems of control which prescribe how the industrial contractor shall perform but add little value to the products.

4.2 COMMONALITY POTENTIALS

4.2.1 INTRODUCTION

A basic objective of the EOS Study is to provide a design for a General Purpose spacecraft with sufficient flexibility to accommodate the EOS-A mission requirements as well as a number of follow-on mission payloads. The general approach, therefore, during the study was to establish the driving requirements for each subsystem and to provide a design for those subsystems which could indeed allow them to be utilized for various missions. Each subsystem was investigated in this regard and the results of each cost/design tradeoff is presented in individual sections of Volume 3 of the study, "Design/Cost Tradeoff Studies". The cost saving measurements for commonality are quantified in each individual technical tradeoff study with a resultant selection of the best commonality approach. This section will summarize the overall results of these individual studies in terms of providing a listing of some of the common hardware items and the number of units that would afford the best "low cost" make/buy approach predicted upon the mission model that was used for the study.

4.2.2 HARDWARE SELECTIONS FOR COMMONALITY

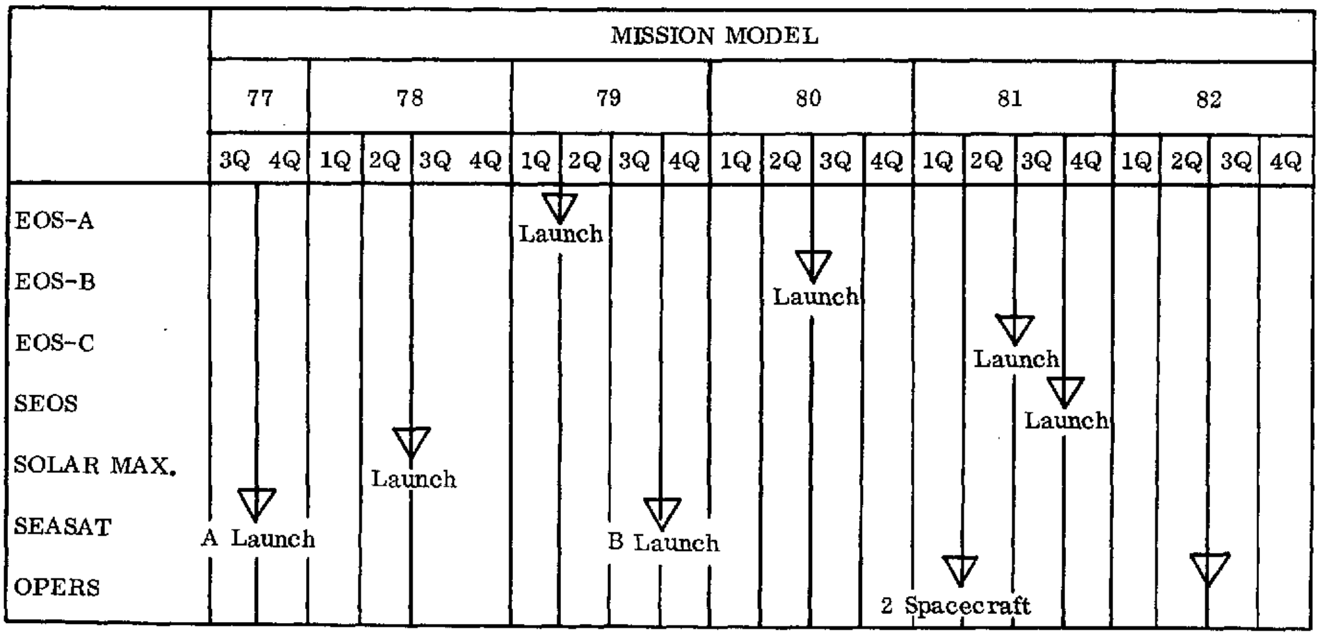
The following table presents on a "subsystem" level, the elements of the General Purpose spacecraft to which the commonality approach is readily applicable. The hardware has been chosen/designed to provide maximum flexibility for presently contemplated future applications. The subsystem modules have been designed to provide capability for launch on a Delta 2910 with growth capability (using identical hardware at the component level) for launch on the Titan IIIB, and subsequently, the Shuttle.

Although this table represents only the General Purpose Spacecraft in terms of commonality buys, the same approach could be considered in the ground station area, especially the low cost ground stations. The Antenna, Receiving, Recording, Processing and Display Subsystems could be purchased as a multiple buy with attendant cost savings.

Common Hardware Differences - General Purpose Spacecraft			
Subsystem	Delta 2910	Titan IIIB	Shuttle
ACS Module	Same	Same	Same
Power Module	2 Batteries 77 ft^2 Solar Array	3 Batteries 109 ft^2 Solar Array	3 Batteries 109 ft^2 Solar Array
C&DH Module	1 OBC	2 OBC	2 OBC
Structure	Modified Transition Ring	Transition Ring	Transition Ring
Thermal Control	Similar	Same	Same
Electrical Dist.	Similar	Same	Same

4.2.3 MISSION MODEL

The mission model used in the study is presented below:



	QTY PER S/C	TOTAL NO. REQUIRED	SHELF LIFE
ACS MODULE			
BACKUP CONTROLLER	1	5	>5 YEARS
MAG. COMPENSATOR	3	15	>5 YEARS
MAG. CONTROL	1	5	>5 YEARS
MOMENTUM WHEEL	3	15	>10 YEARS
ELECTRONICS, WHEEL	1	5	>10 YEARS
STAR TRACKER	1	5	>10 YEARS
IRU PLATFORM	1	5	>10 YEARS
SOLAR ASPECT SENSORS	6	30	>10 YEARS
MAGNETOMETER	1	5	>5 YEARS
POWER MODULE			
CENTRAL CONTROL UNIT	1	5	>5 YEARS
POWER REGULATION UNIT	2	10	>5 YEARS
POWER CONTROL UNIT	1	5	>5 YEARS
BATTERY	2	10	>10 YEARS UNCHARGED
REMOTE DECODER	2	10	>5 YEARS
REMOTE MUX	2	10	>5 YEARS
S/C INTERFACE ASSY	1	5	>10 YEARS
TEST CONNECTOR ASSY	1	5	>10 YEARS
SOLAR ARRAY	1	5	>10 YEARS
C&DH MODULE			
S-BAND TRANSPONDER	1	5	>5 YEARS
MOD SWITCHING	1	5	>5 YEARS
CNTRL. DEMODULATOR	1	5	>5 YEARS
FORMAT GENERATOR	1	5	>5 YEARS
CLOCK - UNIT	1	5	>5 YEARS
REMOTE TELEMETRY	1	5	>5 YEARS
REMOTE COMMAND	1	5	>5 YEARS
S-BAND ANTENNA	1	5	>10 YEARS
PROCESSOR	1	5	>5 YEARS
MEMORY - CMP	1	5	>5 YEARS
POWER CONV. - CMP	1	5	>5 YEARS
SPECIAL IO - CMP	1	5	>5 YEARS
STRUCTURE			
STRU. ACS MOD	1	5	>10 YEARS
STRU. POWER MOD	1	5	>10 YEARS
STRU. C&DH MOD	1	5	>10 YEARS
STRU. BASIC S/C	1	5	>10 YEARS
THERMAL CONTROL			
BLANKETS INS.	1	5	>10 YEARS
THERMAL COATING	1	5	>10 YEARS
HEATERS	1	5	>10 YEARS
ELECTRICAL DISTRIBUTION			
WIRE ACS S/S	1	5	>10 YEARS
WIRE POWER S/S	1	5	>10 YEARS
SIGNAL CONDITIONING	1	5	>10 YEARS
WIRE SPACECRAFT	1	5	>10 YEARS
WIRE C&DH S/S	1	5	>10 YEARS

Figure 4-1. **General Purpose Spacecraft Components Required To Support 5 Missions (Delta 2910)**

It would appear advisable to purchase or manufacture five sets of flight hardware to benefit from the cost savings of a multiple purchase. The General Purpose Spacecraft as presently conceived could support the first missions shown on the model; Seasat A, Solar Maximum, EOS-A, Seasat B, and EOS-B mission. The number of components involved in this multiple buy are shown in Figure 4-1. The subsystems are indicated as well as the major components required and the capability of these components to support the first five missions.

4.2.4 SHELF LIFE

Shelf life of the hardware as shown in the table indicates that hardware manufactured in 1975 could be considered to be reliable for a 1980 launch and a two-year orbit life, providing that certain storage conditions and exercise of selected components is conducted on a regularly scheduled basis. Studies conducted on other programs indicate that if the spacecraft is stored in a clean, dry (60% RH or less) non-magnetic and non-UV environment that there should be no storage problems. Some components require special storage techniques such as:

- Batteries should be enclosed in plastic bags and packed with dessicant bags. After packaging, modules are to be stored at a temperature of $5 \pm 5^{\circ}$ ($41 \pm 9^{\circ}$F) in a refrigerator or freezer. Periodic testing should be conducted.
- C and DH components should be stored in an environment in which the magnetic field is less than 50 gauss. Periodic tests should be conducted.
- ACS gyros must be stored with the spin axis horizontal. Many oils and greases will tend to creep in stationary bearings. Provision should be made for periodic exercise of such bearings.
- Other aspects of storage that must be considered are such items as cold flow or permanent deformation of rubber, elastomeric or plastic materials under mechanical stress, oxidation or ozonation, and UV light discoloration of coatings. However with proper procedures and replacement of specific parts, shelf life of hardware can be increased considerably.

4.2.5 RECOMMENDATIONS

In summary, the recommended approach to low cost hardware commonality on the EOS Program consists of the following:

- Multiple buys of hardware with a minimum purchase of sets for at least five spacecraft.
- Design of the General Purpose spacecraft to use the same hardware to perform multi-mission requirements.
- Since shelf life of 5 years for spacecraft hardware does not appear to be a problem based upon previous studies conducted, that certain storage environments be provided, and that selected components be exercised and retrofitted as required.

4.3 CONTRACTING TECHNIQUES

4.3.1 INTRODUCTION

One of the areas of analysis recommended by NASA and concurred with by the GE Management Review Team was contracting techniques between NASA and Industry. This subject has been the object of much attention by both Government and Industry agencies in the past. A review of available data indicates that a case for or against any contracting technique can be made dependent upon the particular set of cost incurring circumstances and the objective the the analyst. For these reasons the EOS Study Team analyzed contracting techniques with a view towards recommending a contracting technique which would facilitate the interface between NASA and Industry and which would allow NASA to relax its control of the contractors without fear of obtaining a less capable product. This lessening of control and easing of interface should tend to reduce costs.

The results of this analysis indicate that the most effective techniques for the EOS Program would include:

- Multiple contractors - spacecraft system and instruments
- A two-phase contract which separates development and production
- Application of "Design-to-Cost" techniques (See Para. 4.8)

- o Providing the same contracting basis for all contractors
- o A combination of incentive and award fees with successive targets
- o Inclusion of Value Management provisions (See Para. 4.9)

To be cost effective, any contract requires an equally aggressive program of participation and support on the part of both NASA and the contractor. The type of contract recommended creates this environment wherein both parties are working toward the same objective of a low cost program.

4.3.2 METHOD OF CONTRACTING

In the analysis of the method of contracting, three basic methods of contracting were considered: a single prime system contractor, multiple prime contractors for system elements, and prime and associate contractors.

METHOD 1 - Single Prime System Contractor

In this method NASA would contract with a single contractor for the spacecraft, the instruments, and the ground data handling system as depicted in Figure 4-2.

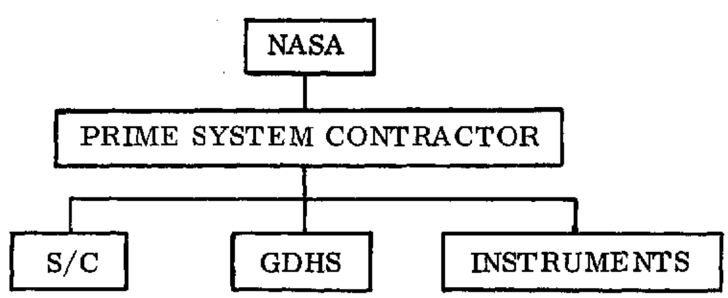


Figure 4-2

This method is a very attractive one since NASA has a single point of responsibility for the entire spacecraft system with no requirements for NASA to act as the coordinator of multiple contractors. It places the full burden of systems management on the Prime System Contractor. However, it is not a practical contracting method because of the disparity in development and fabrication cycles between spacecraft and instruments. In view of the long lead time required for instrument development, this method of contracting would necessitate selecting the prime system contractor before he would be needed to begin spacecraft development undoubtedly at an increase in cost of the total program.

METHOD 2 - Multiple Prime Contractors

In this method, NASA would go to the other end of the scale and contract separately for the major program segments such as is depicted in Figure 4-3. In this approach the interface between NASA and Industry is greatly expanded since NASA is now responsible for the integration of four or more contractors. It is easy to see that the degree of control required to keep these contractors in technical and schedule consonance is heightened as would be the interface coordination between all system segments. This method is very undesirable since it obviously tends to increase program control requirements, expends the interface points, and makes more difficult NASA's directive responsibility. It promises to be quite unwieldly and appears to proliferate costs.

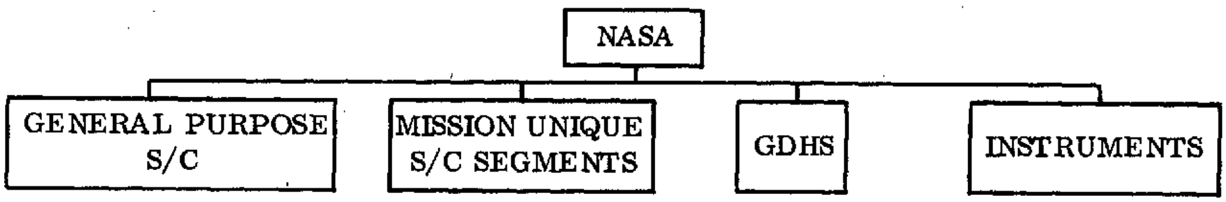


Figure 4-3

METHOD 3 - Prime and Associate Contractors

This method is a minor adaptation of the current practice of a spacecraft system contractor and a number of instrument contractors wherein NASA retains responsibility for instrument development and fabrication and for coordinating the interface between the spacecraft system contractor and the instrument contractors. The difference being recommended is that at the earliest practical date, NASA delegates technical direction of the instrument contractors to the spacecraft system contractor. This, as shown in Figure 4-4, would decrease the technical coordination of day-to-day activities between the contractors but would allow NASA to retain contractual direction of all contractors.

Method 3 offers many advantages over other contracting methods because it

- o enables GSFC to trade cost, schedule and performance between the instruments and the spacecraft system,
- o utilizes NASA's on-board expertise to fullest advantage in instrument development,
- o reduces the NASA-S/C contractor - instrument contractor interfaces,

- provides effective contractual control over the minimum required number of contractors,
- allows initiation of firm instrument development contracts before initiation of prime system contract as required by development cycles.

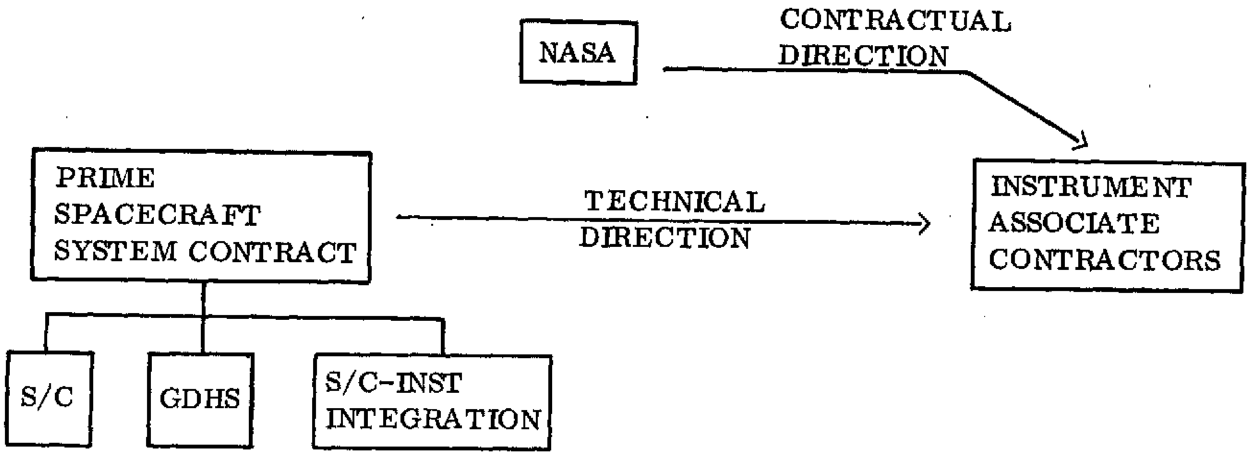


Figure 4-5

4.3.3 CONTRACT STRUCTURE

4.3.3.1 Type Contract

The next consideration was to determine the most appropriate type of contract for the total program. As an aid in the evaluation, Table 4-7 Analysis of Contract Types vs. Requirements was derived. Of the four types of contracts analyzed, it was determined that no single type of contract meets the total objectives of a development/production program.

The rationale leading to this conclusion is as follows:

Fixed Price. Fixed Price contracts are applicable to any contract wherein the work to be performed and products to be delivered are sufficiently well defined to allow for accurate costing. Fixed Price contracts place the greatest risk on the contractor. The lack of effort and product specifity which makes pricing nebulous causes a contractor to include "safety factor" costs in his pricing to balance the risk he incurs. This is not conducive to low cost pricing.

Figure 4-7. Contract Types vs. Requirements

Requirements For Types of Contracts	Type & Complexity of Item	Stability of Design	Adequacy & Firmness of Specs	Number of Technical Unknowns	Ground Rules/ Design/Changes	Definiteness of Test Requirements	Prospective Period of Performance	Known Extent of Subcontracting	Firmness of Subcontracting Specs	Prior Production Experience	Reliability of Cost Estimates	Price Data	Contingencies	Outside Influence Factors
Firm Fixed Price	Std. Comm. or Modified Item	Fixed	Fixed	None	None Expected	Fixed	Any	Fixed	Fixed	Yes	Excellent	Known	None	None
Fixed Price/ Escalation	Std. Comm. or Modified Item	Fixed	Fixed	None	None Expected	Fixed	Any	Fixed	Fixed	Yes	Excellent	Few Conting.	Few May Exist	None
Fixed Price Incentive (Firm Target)	Complex Item	Very Good	Very Good	Very Few	Very Few Expected	Very Good	Any	Very Firm	Good	Preferred	Good	Good	Very Few	Very Few
Fixed Price Incentive (Successive Targets)	Complex Item	Reasonably Tight	Reasonably Tight	Uncertain Initially Becomes Firm	Some Changes Expected Initially	Uncertain Initially Becomes Firm	Long	Uncertain Initially Becomes Firm	Uncertain Becomes Firm Later	Not Necessary	Good	Uncertain Initially Becomes Firm	Some Progress Eliminated	Minimum
Prospective Price Redetermination	Complex Item	Firm	Firm	Firm Outset-Changes W/Time	Some Expected	Firm Outset-Changes W/Time	Very Long	Firm Outset-Changes W/Time	Firm Outset-Changes W/Time	Not Necessary	Good Outset-Changes W/Time	Reasonably Certain	Few	Minimum
Retroactive Price Redetermination	Where Cost Type Normally Used	Not Firm	Not Firm	Few	Few	Not Firm	Short	Not Firm	Not Firm	Not Necessary	Fairly Good	Reasonably Certain	Few	Some
Cost Plus Incentive Fee	Complex Item	Adequate For Start Changes Expected	Adequate For Start Changes Expected	Many	Many	Not Firm	Long	Reasonable Knowledge	Adequate For Start Changes Expected	Not Necessary	Fairly Good	Reasonably Detailed	Yes - Progressively Eliminated	Many
Cost Plus Fixed Fee	Complex	Not Fixed	Not Firm	Many	Many	Not Firm	Any	Not Firm	Not Firm	No	Perhaps Poor	Little Detail	Yes	Many

Cost Reimbursement. This type of contract is suitable for use when uncertainties in performance, design, etc. are of such magnitude that the cost of contract performance cannot be estimated with sufficient reasonableness to permit use of the fixed price type contracts. While this type of contract overcomes the problem of obtaining reliable pricing data, it tends to be more costly than fixed price. This type of contract also places the greatest risk on NASA and inherently allows incorporation of design features which do not contribute to program objectives. This type of contract does not provide the contractor with the motivation to meet NASA objectives of low cost, performance, and schedule.

Other Contract Types. Other contractual types such as redeterminables, time and material, labor hours, were analyzed and considered to not offer potentials for a cost effective contract, nor do they provide the contractor with the necessary prime drivers to exceed contract requirements. They require greater surveillance and are more burdensome administratively. The analysis of applicability of contract type to EOS-A therefore led to the conclusion that (a) no single type contract serves the total program; (b) in developing a cost effective contract, consideration must be given to NASA program objectives in conjunction with the three system segments -- spacecraft, GDHS, and instruments; (c) the type of contract must have the flexibility to meet the needs of the program as it evolves, and (d) a phased contract which contains features of both fixed price and cost reimbursable type contracts, with incentive/award fees should be considered.

4.3.3.2 Phased Contracts

Further analysis of the applicability of contract types solidified the conclusion that the prime contract for the spacecraft system should be in two phases, the development phase and the manufacturing phase. This allows for the application of a cost plus contract for the development phase and a fixed price for the manufacturing phase each being most appropriate for the effort to be performed in those respective phases. This approach also provides a proper contract structure for a design to cost technique as discussed in Section 4.8.

4.3.3.3 <u>Incentive/Award Structure</u>

Fee is the principle method for motivating the contractor to meet NASA's objectives, emphasizing low cost, performance, and schedule.

Various types of contract fees were considered (Table 1); however, the analysis was confined to three types for the Phase I contract and two for Phase II contract. The purpose of the matrix (Table 2) was to determine the type of contract fee which would best motivate the Contractor to perform as the program progresses. A numberic value was assigned on the basis of desirability from NASA's viewpoint, with 1 being the most desirable and 3 the least desirable.

Table 4-8. Program Objectives Related to Contract Structure

	PHASE I			PHASE II	
	CPFF	CPIF	CPAF	FP	FPI
<u>SYSTEM PERFORMANCE</u>					
Quality	2	1	1	2	1
<u>COST CONTROL</u>					
Direct Cost	3	1	2	1	1
Indirect Cost	3	1	2	1	1
Funding Work Arounds	3	2	1	1	2
<u>SCHEDULE</u>					
Hardware	3	1	2	2	1
Software	3	1	2	2	1
Reports - Technical	2	2	1	2	2
- Managerial	2	1	1	2	1

Less obvious, but important, concerns to the performance of any program and the type of contract structure which would best motivate the contractor and provide a basis for control by the Government were also analyzed although it is difficult to attribute to them direct cost savings. (Table 4-9)

Table 4-9. Program Objectives Related to Contract Structure

	PHASE I			PHASE II	
	CPFF	CPIF	CPAF	FP	FPI
OTHER					
Technical Direction	1	2	1	1	2
High Level Management Support	3	2	1	1	1
Management Response to Solving Total System Problems	2	1	1	1	1
Fast Responsive Communications	3	2	1	3	2
Cooperation with Other Associates	3	2	1	3	2
Subcontract Management Integration and Control	2	1	1	1	1
Accuracy of Reporting	2	1	1	1	1
Cost of Change Negotiations	1	2	1	2	2

It was concluded that a combination of incentives and awards contract structure would be most appropriate for the cost plus development of the EOS Program. The strongest motivation on any contractor is to tie significant profit incentives to overall performance, costs control and schedule. Therefore, the following should be considered:

Type	Incentive/Award Schedule
Award Based On	o Management Performance
	o Degree of Program Integration
	o Innovative (Low Cost) Changes
Incentives	o Cost
	o Schedule
	o System Performance
Minimum Fee	o Stipulated - To Cover Cost Disallowances

It is also proposed an award be paid at the conclusion of the program. This award should be primarily for the business management and technical performance on the program. This award would provide a means for adjusting the final award so that the incentives will be consistent with the contractor's final performance. This award would cover intangible items such as:

- o Control of Major Subcontractors
- o Quality of Technical Performance (PDR, CDR, Integ. and Test)
- o Response to Solving Total System Problems
- o Superior Output
- o Work Around Funding Limitations
- o Management Responses
- o Failure Correction

The incentive and award combination should be structured so that heavy emphasis can be placed on both cost and performance and in addition, provide for a method to measure management responsiveness.

Performance incentives, while emphasizing performance of contractor supplied hardware, should also emphasize total system results, thereby motivating the contractor to perform in a manner designed to assure complete system success. Subcontractors (where appropriate) should also share in the incentive so that all are working together as a team.

4.3.3 FIXED PRICE SUCCESSIVE TARGET INCENTIVES

In the analysis, the successive target concept was found to be a most appropriate ingredient for obtaining a cost effective type contract for the Manufacturing phase of the EOS Program.

Under this type of contracting, there is negotiated at the outset of the program:

1. An initial target cost
2. An initial target profit
3. A ceiling price
4. A formula for fixing the firm target profit
5. A production point when the formula applies. The formula is used only to fix the firm target price.

When the production point is reached for applying the formula (for example, delivery of the prototype unit during development phase), the firm target cost is negotiated and the firm target profit is automatically determined in accordance with the formula.

This type of contracting is most appropriate because it requires the contractor to be realistic and objective in his initial approach to the total program and it provides for the gneration of sufficiently reliable cost and pricing data early during development Phase I to permit meaningul negotiation of realistic firm contract targets for the manufacturing phase. This type of contracting requires the contractor to initiate low cost features early in the development program and restrains NASA and the contractor from implementing "nice to have features" which contribute nothing to program objectives.

4.3.4 RECOMMENDED APPROACH

In developing a contracting arrangement for the total EOS Program, the study has led to a concept which will be not only cost effective but also will satisfy NASA needs. Therefore, the following recommendations are made:

1. That NASA award a contract to a prime system contractor who will be responsible for the design, development, manufacture and test of the spacecraft and the ground handling data system and for integration of the instruments into the spacecraft.
2. That NASA also award contracts to the payload contractors who then become associate contractors at the appropriate point in time and thereafter take technical direction from the prime system contractor and contractual direction from NASA.
3. That the prime system contract be structured into two phases consisting of the following:

   Phase I - CPIF/AF for the development and manufacture of a prototype spacecraft and for the design of the ground data handling data system. That the contract be so structured to motivate (through incentive and award features) the contractor to fulfill NASA objectives. Candidates for the incentive/award features to include schedule, cost, management responsiveness, engineering quality, innovative low cost changes, and prototype acceptance criteria.

Phase II - Fixed Price Successive Target Incentive for the manufacture of the spacecraft, integration and test of total observatory system and the manufacture of the ground handling data system. The incentive candidates to be schedule, cost and flight performance.

The approach recommended is considered to be the most cost effective because:

- o it provides the flexibility of sharing the risk between NASA and the contractor. Both parties working toward a common goal
- o it places a ceiling on the contract price
- o incentive features motivate the contractor to meet NASA objectives of low cost, performance, and delivery
- o the successive target features require the contractor to be innovative during the development phase
- o cost information and basis for sound estimates become available during the development phase so that both parties can negotiate realistic costs
- o it obligates the contractor to a price for the production phase prior to the beginning of the production phase
- o it places emphasis on the contractor and NASA to implement changes prior to PDR and no later than CDR
- o it places parameters on the contractor during the development phase
- o it contributes to "designing right the first time"
- o it initiates safeguards against the "this would be nice to have or let's play it safe and throw in an extra measure for performance" syndrome
- o it reduces the long established tendency to demand features pressing the state-of-the-art and over-sophistication during the early cycle of the program
- o it precludes unnecessary elements from creeping into the final design.

4.4 SUBCONTRACTING TECHNIQUES

The analysis of the subcontracting techniques is redundant to the contracting techniques contained in Section 4.3. For this reason, it is not repeated in this section. It is standard practice, and properly so, to prepare all subcontracts in the image of the prime contract because the responsibilities which the prime contractor assumes cannot be properly assumed unless these identical responsibilities are placed on the subcontractors. The application of method and type of contracts for subcontracts is identical to that of prime contracts discussed in Section 4.3.

4.5 TEST PHILOSOPHY

4.5.1 INTRODUCTION

The unique aspects of the EOS design approach have been thoroughly studied and compared to programs now in progress or recently completed. This study led to a viable test philosophy and program that could be effectively implemented in two steps. The first step step moves from the present approach to the EOS-A program and the second step carries the cost reduction techniques even further for additional savings in the follow-up spacecraft test programs.

Prime considerations were given to the effects of multiple missions utilizing identical spacecraft bus hardware, fully modular design, on-orbit repair by replacing subsystem modules, on-board computer utilization for test and troubleshooting, and reducing the effort expended on various spacecraft models as the overall program progresses through several spacecraft.

Figure 4-5 shows a summary test flow of the various approaches considered in the study and Table 4-10 shows the degree of tests performed in each area, including spacecraft models considered for each test program.

Cost estimates were then made for the three types of test programs. A summary of these costs are provided in Table 4-11. This clearly shows the net reduction in total costs

Table 4-10. Test Program

	Typical S/C	EOS-A	Follow-on EOS
S/C Models			
Thermal	Yes	No	No
SDM	Yes	Yes	As Required
Antenna	Yes	As Required	As Required
Harness M/U	Yes	Yes	As Required
Component			
Qualification			
Elec. Perf.	Yes	Yes	No
Mechanical	Yes	Partial	No
Environmental	Yes	Partial	No
Flight			
Elec. Perf.	Yes	Yes**	Yes
Mechanical	Yes	Partial	Partial
Environmental	Yes	Partial	Partial
Subsystem or Module			
Qualification			
Elec. Perf.	No	Yes	No
Mechanical	No	Yes	No
Environmental	No	Yes	No
Flight			
Elec. Perf.	Yes	No*	Yes
Mechanical	No	No*	Yes
Environmental	No	No*	Yes
System			
BIT	No	Yes	As Required
Prototype S/C	Yes	No	No
Proto-Flight			
Elec. Perf.	No	Yes	No
Mechanical	No	Yes	No
Environmental	No	Yes	No
Flight			
Elec. Perf.	Yes	No*	Yes
Mechanical	Yes	No*	Yes
Environmental	Yes	No*	No

* Qual unit(s)/Subsystem(s) used for flight

** Additional unit(s) needed where qual units not available as the program progresses. This is primarily achieved by the reduction of required test models and the reduction of large test crews required for long, full system level test programs.

Table 4-11. Estimated Test Costs

	PRESENT	EOS-A	FOLLOW-ON EOS
S/C Models	980K (24%)	510K (19%)	180K (15%)
Component	920K (23%)	430K (16%)	430K (35%)
Subsystem or Module	72K (2%)	144K (5%)	144K (12%)
System	2100K (51%)	1550K (60%)	460K (38%)
Totals	4072K	2634K	1214K

$\Delta^{(1)}$ |←— 1438K —|— 1420K —→|

$\Delta^{(2)}$ |←—— 2858K ——→|

Development tests are unique to each program and would be included in the non-recurring costs of each program; therefore, a discussion of purely development test programs would be subjective and would not provide a meaningful trade-off. In line with this, development testing involving breadboards, brassboards, etc. is not discussed further in this write-up.

4.5.2 PRESENT TEST PHILOSOPHY

The present test program approach has evolved over the years and has been modified as a function of the life requirements for the particular programs. To achieve on-orbit performance for long life spacecraft, it was necessary to provide redundancy for mission critical components and/or subsystems and to provide extensive test programs to assure that all alternate operational modes are thoroughly checked out and trouble free prior to launch. One of the predominant features of the present philosophy is the extensive environmental tests performed from the component level through the subsystem and system level. This level of tests is time consuming and often requires large test crews to maintain around-the-clock tests.

Figure 4-5 illustrates the test flow for a typical long life spacecraft. In this approach, an Engineering or Prototype Spacecraft is fabricated and fully tested to assure that the various subsystem interfaces are correct, and that the various operational modes, operational software packages and the ground system are integrated into an operational system. Following this, the flight system is fabricated and checked out through various levels of tests prior to launch. This has been a successful test program for achieving long life spacecraft to date, but is not deemed necessary in the shuttle era.

4.5.2.1 <u>Qualification</u>

Based upon results of the development testing, prototypes of components and systems are then fabricated. This hardware is then subjected to a full prototype environmental test program at the component levels. After completion of the component qualification tests, the units are assembled in a prototype spacecraft and subjected to additional qualification tests at the systems level. The test program is very extensive including electrical performance at prescribed milestones, RF testing, vibration testing, acceleration testing, thermal-vacuum and sometimes thermal balance. If acoustics is a significant problem, acoustic testing is also performed.

The prototype spacecraft is then placed in storage or maintained as a test bed for future troubleshooting modes. While the prototype does provide a useful function, it is an expensive approach requiring a complete spacecraft.

4.5.2.2 <u>Acceptance</u>

Flight hardware normally is subjected to performance and environmental testing at the component and system levels. This program, although at lower environmental levels than for the prototypes, covers the same test at different levels and for different test durations. As shown in Figure 4-5 and Table 4-10 the components are submitted to full acceptance tests then assembled into the spacecraft and subjected to additional acceptance tests at the Spacecraft level. The penalty for this concept is time and dollars, the latter being quite significant as shown in Table 4-11.

4.5.2.3 Spacecraft Models

The typical spacecraft design also includes the fabrication and test of various models to assure that the fundamental designs are sound. Each of these models plays an important role in the development of a new spacecraft, but the role becomes less and less significant as additional spacecraft of similar designs are provided.

Thermal Model. Thermal models are provided to confirm the adequacy of the thermal design of a spacecraft. As the spacecraft design develops, a thermal analytical model of the spacecraft is also developed. From these a model is fabricated incorporating "like prime" structure and actual or simulated thermal components are mounted in the structure. The model is then subjected to the prescribed thermal environments. If deviations occur, then corrective design measures are incorporated and the analytical model is updated accordingly. Thus, the final design is approached in an iterative manner. Computer programs have been developed to perform this complex analysis and can be readily modified to incorporate the changes as required.

Structural Dynamics Model (SDM). The structural development model consists of a full scape primary and secondary structure of the spacecraft including mass models of all major components or assemblies, installed in their respective flight configuration. The SDM is utilized to: confirm dynamic analytical models; demonstrate the structural integrity of the design for qualification; confirm the dynamic internal environments for subsystems and components; confirm the dynamic envelope within the fairing; confirm separation clearances; confirm partial spacecraft and mechanical AGE/support equipment compatibility and to develop dynamic environment test techniques for the Flight Vehicle. Testing includes launch and orbital vibrations, static load tests or steady state acceleration and shock as necessary to achieve the test objectives.

Antenna Model. Antenna model spacecraft are normally provided on new designs. These models are checked out on antenna ranges to assure that the gain and patterns are consistent with the design requirements. Normally, these are made of material that provides the RF characteristics of the spacecraft. However, they do not require prime type material in most areas.

Harness Mock-Up. A harness mock-up is used as a development tool and is made to prime dimensions. Mock-up harnesses are then assembled in place until the placement of all harness segments is completed. These segments are then removed and three dimensional boards made up from the mock-up harnesses. All flight harnesses are then fabricated in the proper configuration on these boards. This is an extremely useful model as it eliminates the extensive handling required to mount prime harnesses in the proper configuration.

4.5.3 RECOMMENDED EOS TEST PHILOSOPHY

The modular approach to the spacecraft design provides for a logical reduction in system level tests and system level models. As shown in Figure 4-5 and Table 4-11 a significant reduction is achieved in test and test cost as the transition is made from the typical spacecraft to EOS-A and then to the Follow-On EOS programs. This new philosophy is based on the concept of investing development funds in the initial phases of a program and relying (rather than retesting) on the results throughout the program. This concept is also consistent with successful commercial test programs.

4.5.3.1 EOS-A Test Philosophy

The EOS-A test philosophy is based on combining flight proven/qualified hardware with the new modular design approach of the EOS system. Therefore, some of the old concepts will be integrated with the new test approach to assure meeting the orbital life requirements of the spacecraft. In this approach one prime spacecraft will be fabricated and processed through a combination of prototype and flight environments.

4.5.3.1.1 Spacecraft Models

An SDM and Harness Mock-Up will be fabricated and utilized as described in Section 4.5.2.3 and maintained for use on the follow-on EOS spacecraft. An Antenna Model will be fabricated as required based on the final configuration of the EOS-A spacecraft.

The modular design approach of the EOS spacecraft greatly simplifies the analytical thermal model of the spacecraft. Since each module is thermally isolated from the structure and the other subsystem modules, the analytical approach and computer programs are relatively easy to perform. In addition, the history of previous programs establishes the high degree of correlation between analysis, test data and on-orbit data. Therefore, the spacecraft Thermal Model is not considered necessary for the EOS Program.

4.5.3.1.2 Bench Integration Tests (BIT)

A Bench Integration Test program should be implemented on EOS-A in place of an Engineering or Prototype Spacecraft. The basic configuration of this approach will include all the Engineering components in the subsystem arrangements; however, the components and test points are readily accessible for ease of integration. The interconnecting harnesses duplicate the wire size, number, shielding and connections of the flight spacecraft harness so that conducted RF, voltage drops, etc. will be representative of that found in the flight spacecraft.

This approach also provides an opportunity to integrate the spacecraft electrical subsystem early in the program to provide an evaluation of system electrical and RF compatibility. It also serves to checkout electrical test equipment compatibility, test ground station operation, establish test procedures and checkout test software sequences. Thus a large percentage of the results achieved in a prototype spacecraft will be obtained in this configuration at a much lower cost.

The BIT Board should be maintained throughout the EOS program and used as a test bed for new payloads or mission peculiar subsystems.

4.5.3.1.3 Qualification Program

As in all new programs there will be some requirements that will necessitate new or modified component designs. In addition, this will be the first spacecraft with the modular design approach; therefore, it is deemed necessary to provide a higher degree of testing on EOS-A than on the follow-on spacecraft.

An evaluation of both the EOS-A Configuration and the follow-on EOS Configuration was made to determine feasible approaches to solving both problems with minimum test and coast as a goal. Thus the qualification program shown in Table 4-10 was arrived at.

For new designs the components would be subjected to electrical performance tests, workmanship vibration and a temperature cycle test. Upon successful completion of these tests the components would be mounted within the respective subsystem module along with the flight units that had passed similar tests.

Since EOS-A is not repairable in orbit and the subsystem modules are identical to those used on the follow-on EOS spacecraft it was decided that the modules should be fully qualified on EOS-A.

4.5.3.1.4 Spacecraft Tests

As shown in Table 4-10, the EOS-A spacecraft is a proto-flight system. Proto-flight is defined as testing the system to qualification levels for flight duration requirements. Thus, the proto-flight test sequence provides both the flight qualification and acceptance test functions. This will provide the basic systems level qualification tests for EOS-A and the follow-on spacecraft. An additional advantage this spacecraft has over the typical spacecraft, discussed in Section 4.5.2, is the incorporation of an On-Board Computer. The Computer can be programmed to provide different sampling rates for telemetry functions, monitor critical functions and flag an out-of-limits condition if or when it occurs or provide command capability to modify the spacecraft operation in the event of specific malfunctions, etc. Therefore, the OBC can be used as a useful diagnostic tool, provide a means for modifying the system operation when specific anomalies occur and aid in the overall test programs.

4.5.3.2 Follow-On EOS Spacecraft Test Philosophy

The follow-on EOS spacecraft test philosophy is readily derived from the preceding sections. Additional factors to be considered here are the on-orbit retrievable and repair capability provided by the Shuttle. Thus a much reduced test program is realistic and achievable.

4.5.3.2.1 Spacecraft Models

The necessary EOS spacecraft models are provided during the EOS-A phase of the program. Those required to be retained and modified for the follow-on EOS spacecraft are the SDM, Antenna Model, and the Harness Mock-Up. A significant reduction in cost is achieved by this method as shown in Table 4-11.

4.5.3.2.2 Bench Integration Test (BIT)

The BIT Board described in Section 4.5.3.1.2 will be modified in accordance with new and modified payloads and/or other mission peculiar subsystems. Again it is readily seen that this is an area where significant cost savings can be achieved.

4.5.3.2.3 Qualification Program

All qualification level tests were performed on EOS-A. Therefore, no additional qualification tests are anticipated for the follow-on EOS spacecraft.

4.5.3.2.4 Acceptance Test

Partial or complete acceptance tests will be performed at all levels. The components will be subjected to a complete electrical performance test, workmanship vibration test, and a thermal cycle test. Upon successful completion of these tests the units will be mounted in the subsystem modules and a complete flight level acceptance test will be performed.

After the modules successfully pass the acceptance test they will be placed on the spacecraft for a full electrical performance test and a vibration test representative of the flight loads.

4.5.4 TEST IMPLEMENTATION

Test implementation techniques in the areas of procedures, data evaluation, ground support equipment, ground station operation, test personnel and overall test requirements have been examined and evaluated to determine optimum cost effective methods for implementing the EOS test program

Procedures. Since spacecraft development and qualification will be implemented through EOS-A, test procedures for this vehicle should be detailed in nature. All interfaces should be minutely examined during integration and system procedures should be slanted toward quantitative performance analysis. Testing should be designed to produce maximum operating time on hardware consistent with component life limits and mission requirements.

The effort for follow-on vehicles should be directed toward standardization and minimum system testing. Since EOS should have a standard basic spacecraft for all missions, it is completely consistant with reliability requirements to plan procedure effort to effect the following economies:

a. Standard basic spacecraft integration procedures for all vehicles after EOS-A.

b. Minimum spacecraft integration, possibly only assembly into the structure, harness connection and brief functional check.

c. Computer controlled tests, utilizing the on-board computer for commanding and limit checking of telemetry.

d. Only one system qualitative (go/no go) functional test to be utilized throughout the program whenever a functional test is required.

Evaluation. In-depth evaluation will be necessary for EOS-A. This means extensive manual analysis of spacecraft data, particularly for the basic spacecraft since it is imperative that basic spacecraft reliability be established beyond question for this vehicle. This technique thus lays the groundwork for reducing extensively the manual evaluation required for follow-on vehicles for basic spacecraft testing. Once spacecraft performance parameters and reliability have been firmly established, barring significant hardware changes, later evaluation can be readily relegated to automated computer techniques. It is envisioned that limit-checking probably with the on-board computer will provide the bulk of evaluation necessary for follow-on spacecraft performance. Backup ground station computers should be available also to perform this function. Software, generated during EOS-A qualification should be designed for use in either on-board computer or ground station computer.

Ground Support Equipment. The concept of a universal assembly, test, handling and transport fixture should be investigated and implemented to the greatest extent possible for EOS. Such a fixture offers potential for significant savings in the following areas:

a. Once assembled in the fixture the spacecraft is not removed until ready for mate to the launch vehicle, saving the time of numerous fixture transfer moves during the program.

b. The cost of a single fixture versus the cost of multiple fixtures (i.e., assembly fixture, ambient test fixture, T/V fixture, transport dolly, etc.) should be analyzed.

Electrical GSE should be minimized. Basically, it should provide essential powering and monitoring facilities for controlling the spacecraft. Since system testing will be minimized, special test equipment racks such as deployment console, RF console and solar array simulator should not be required at the system level; however, equipment requirements for testing at the module (subsystem) level will increase and the net savings may well be zero.

Ground Station. Test ground station requirements for the basic spacecraft are not expected to be significantly different than those presently in force. Although the OBC should be used for spacecraft control and evaluation to the greatest extent possible, backup capability must exist in the ground station to program and check the OBC, display data output by the OBC and T/M link and to take over spacecraft control in event of OBC malfunction. The greatest saving in the ground station area should be in the area of manpower.

It is expected that payload ground stations would be supplied with the instrument or a type of the instrument output as required, and would be primarily of a go/no go checkout design requiring minimal attention.

Personnel. One of the major cost drivers in a system test program is personnel. Traditional programs encompassing detailed integration, multiple quantitative functional tests, full environmental testing, mechanical and mass properties determinations and prelaunch testing at the launch site require large dedicated test crews for upwards of six to eight months per spacecraft. System test personnel requirements rise to one hundred or more people for large tests, around the clock, such as thermal-vacuum. For normal multiple shift testing (2 shifts/day, 5 days/week) requirements are will in the 50-man range when all supporting functions such as procedures, evaluation, ground station operations, repair and maintenance and logistics are considered.

EOS can greatly reduce these requirements by vastly curtailing system testing. The elimination or reduction of acceptance environmental testing at the system level and substitution of acceptance at the module level should not only reduce the length of the system test program but also the number of people required for any given test. With this concept, personnel can be reduced in the following areas:

- Standard general purpose spacecraft integration procedures should reduce procedure writing from an average of three to one after procedures have been finalized.
- Utilization of the OBC for checking spacecraft functions on an automated basis without manual checking can reduce evaluation engineer requirements from an average of two to one depending upon payload complexity.
- Simplification and automation of integration and system performance procedures can reduce on-line test crews per shift from an average of two to one.

4.5.5 TEST PHILOSOPHY SUMMARY

To attain significant cost reductions in a spacecraft test program it is mandatory that spacecraft level tests be kept to a minimum. These system tests produce the highest overall costs because:

- o Large, experienced crews are required for testing the spacecraft, manning ground stations and evaluating performance.
- o Test procedures and software are complex, requiring many man-hours to produce and a continuing effort to update.
- o The large environmental test facilities needed are expensive to operate because they require multiple operators.
- o Test installations are massive requiring considerable time to set up and dismantle.

In order to realize the greatest cost effectiveness for the EOS test program, greater emphasis must be placed on comprehensive environmental testing at the subsystem level, while system testing is relegated to the role of "workmanship" and go/no go tests.

Since the EOS program will be a multiple vehicle program utilizing the same basic subsystem modules and structure for each spacecraft, it is uniquely suited for such an approach. The subsystem modular concept also lends itself to this philosophy. Subsystem environmental testing at the module level can be made as fully stringent and realistic as at the spacecraft level. Further, any subsequent module replacement due to malfunction or failure during systems testing can be made with minimum impact on the spacecraft test program because environmental testing has already taken place.

4.6 RELIABILITY & QUALITY ASSURANCE

4.6.1 RELIABILITY PROGRAM

Reliability program requirements for NASA programs are generally specified by NHB 5300.4, entitled "Reliability Program Provisions for Aeronautical and Space

System Contractors", dated April 1970. The provisions of this document are applied in totality, or by specific paragraphs only.

During the many years of implementation of the provisions of this document, it has been found that certain of these tasks make a significant contribution to the removal of unreliability from a space system whereas other tasks have little or no impact on the hardware at all and can be eliminated with no risk to the program and with a consequent cost saving.

Retained Tasks. Those tasks that contribute to the removal or identification of potentially critical design areas are:

- Supplier Control
- Design Specs
- Prediction (tradeoff studies only)
- FMECA's
- Design Reviews
- Failure Reporting and Analysis
- Parts/Materials Program
- Testing
- Maintainability (when required)

These controls, analyses, reviews and programs become increasingly important on the EOS program to reduce cost without unduly inducing additional risk.

Deleted Tasks. The peripheral tasks that do not effect the reliability of the hardware are:

System Reliability Prediction - The prediction technique is generally used to determine the comparable reliability of two or more competing designs. It has little utility as a misused prediction of system performance.

Formal Progress Reports - Informal reporting is recommended.

Reliability Evaluation Plan - The sequence of tests to which equipment is subjected - prototype, development, acceptance and qualification are well established by this time and the formal assessment of reliability from the test results is seldom done.

Reliability Training - This task is currently not done because its purpose has already been achieved, Reliability consciousness has been installed throughout the aerospace industry.

Standardization of Design Practices - The existing standards and specifications are well understood and utilized by the cognizant personnel. The design review process inspects the design and process standards used on a program.

Reliability Inputs to Readiness Reports - The responsibility for this task is usually vested in configuration management.

Reliability Evaluation Program Reviews - This task is seldom done on NASA Programs.

Reliability Program Reviews - The design review process replaces this task on most programs.

Reliability Assessment - See comments under Reliability Evaluation Plan. As is evident, these tasks can be deleted because they have been little used on past programs and their omission from the EOS program will institute some cost savings with minimal program effect.

Proposed Program. A proposed Reliability Program Plan is shown in Table 4-12. The proposed program responds only to the provisions of NHB 5300.4 which are considered necessary to eliminate or alleviate the major and sometimes subtle failure modes from the satellite system and deletes those previously submitted as having little program value.

The program considers not only the selected contractors tasks responsibilities, but also recommends the inclusion of certain provisions in the NASA Statement of Work (SOW) that can influence the NASA/Contractor interface and task responsibilities.

One basic premise on which the plan was constructed was that the customer (NASA) would assign a resident QC&R representative at the contractors facility with the authority for decisions, approvals and problem resolution.

If this premise is not accepted, then the responsibilities delineated in the program for the NASA rep will be carried out formally by the existing NASA/contractor interface.

Other cost effective items are interwoven into the plan and are asterisked whenever they appear.

4.6.2 QUALITY PROGRAM

The basic Quality requirements for NASA programs are defined in Reliability and Quality Assurance Publications NHB 5300.4 (1B), "Quality Program Provisions for Aeronautical and Space System Contractors". Although it was published in 1969, the provisions of this document still provide the ground rules for a well-rounded Quality Program. Each of the defined tasks in NHB 5300.4 (1B) is q required element in any space oriented program, however, certain modifications to these provisions will result in a more cost-effective Quality Program.

In summary, the elimination of any tasks in their entirety is not recommended, but modification of the following tasks is recommended:

1B103	Quality Program Documents
1B204	Quality Status Reporting
1B300	Technical Documents
1B302	Change Control
1B502	Procurements Documents
1B504	Government Source Inspection
1B801	Nonconformance Documentation
1B804	Material Review Board
1B806	Supplier Material Review Board

TASK	NHB 5300.4 TASK NO.	RECOMMENDED NASA RESPONSIBILITY	CONTRACTOR RESPONSIBILITY
Reliability Program Documents	1A104	Specify in the SOW: (1) Minimal formal documents required for review and approval. (2) Provide approval responsibility to a resident QC&R NASA representative. *(3) Accept legible handwritten copies with a cover sheet approval form for signatures. (4) If any document is considered essential for formal presentation outside the NASA-contractor interface - specify formal (typed) presentation.	Contractor will: (1) Provide all documentation at the system and subsystem level only, except that the program manager has the option for lower level documentation. (2) NASA QC&R rep. to interface with the Deputy Program Manager (DPM) to determine: o Approval route for specific documents o Formal document release schedule o Informal document release schedule o Integration of off-the-shelf documentation into subsystem and system analyses and data output.
Reliability Program Plan	1A201	(1) Delete requirements for peripheral tasks which do not impact on hardware. o System rel. prediction (1A302) o Formal Progress Reports (1A203) o Rel. evaluation plan o Standardization of design practices (1A307) o Reliability inputs to readiness reports (1A404) o Reliability evaluation review (1A405) o Reliability program reviews (1A202-2) o Reliability Training (1A204) (2) Retain those tasks that aid in removing unreliability from system: o Supplier control o Design specifications o Prediction (in tradeoffs only) o FMECA's o Design reviews o Failure reporting & analysis o Parts/materials program o Testing o Maintainability Modify these tasks in accord with information in following paragraphs: (3) Specify the role of the NASA QC&R rep. in the reliability tasks as to: o Responsibility o Decisions o Approvals o Boards o Reviews (4) Specify requirements for and use of OTS documents.	(1) Contractor to respond to specific SOW requirements but, in addition, will recommend simplification or other cost savings methods that may be implemented during program. (2) Contractor to show role of NASA QC&R rep, in reliability tasks in the responsive reliability program plan. (3) Contractor to show the integration of the off-the-shelf hardware documentation in the reliability tasks.
Reliability Program Control	1A202	(1) NASA to establish a resident QC&R representative at contractor's plant for an overview of program. Rep. to participate in selected program activities in order to expedite: (1) joint NASA/contractor decisions; (2) approval routes; (3) data and out of scope work request; (4) progress reporting; (5) design reviews.	Contractor to delegate DPM as focal point for QC&R NASA rep, to interface with DPM on all reliability activities. DPM to control reliability activities.
Reliability Program Reviews	1A202-2	Reviews to only be called by NASA rep. when the informal interface is not providing visibility to rep. Reviews should be scheduled as part of system design reviews.	Informal reviews should be scheduled for minimum interference with normal program activities by agreement between DPM and NASA rep.
Reliability Progress Reporting	1A203	NASA QC&R rep. to implement progress reports to NASA via TELECON in conjunction with DPM.	Contractor to ensure all output documents are directed to NASA rep. for information and completion of scheduled milestones.
Supplier Control	1A205	(1) Specify the acceptability of previously prepared documentation from other programs as modified to meet EOS requirements. (2) Specify that the imposition of a reliability program is not required on off-the-shelf equipment suppliers if their equipment has been successfully demonstrated by space flight. (3) Specify that the provisions of NHB 5300.4 imposed on the contractor will also be imposed by the contractor on vendors of new design equipments.	(1) Contractor will implement three levels of controls on vendors from maximum on new design suppliers to minimum on OTS suppliers.
Reliability of GFP	1A206	(1) NASA to provide all experiment hardware to the contractor as Government Furnished Property.	(1) Contractor/NASA to determine documentation requirements on GFP depending on its: o Availability o Currency o Depth
Reliability Prediction	1A302	(1) Specify in the SOW the restriction of the prediction to design configuration tradeoff studies only.	(1) Contractor will do prediction only at the option of design engineering manager. No prediction will be required by subs. (2) Contractor will hold subsystem design engineer responsible for maintaining optimum safety margins on new hardware and subcontracted hardware. (3) Design margins on OTS equipment will be reviewed for applicability to EOS multiple mission environmental ranges. (4) Contractor will require predictions and part application data forms on the OTS hardware in the data package obtained from the vendors in order to review the stress limits on previously used parts. (5) Similar stress analysis on OTS materials should also be provided.
Failure Mode Effects and Criticality Analysis	1A303	(1) Specify FMECA at component level up, except where a critical single point failure exists, then a failure mode analysis may be required at the option of the design engr. manager.	(1) Contractor to analyze as specified and alert design engr. manager to SPF's for decision on follow-up analyses based on item 2 in opposite column. (2) Contractor to integrate off-the-shelf equipment FMECA's into the subsystem or system FMECA. (3) Contractor will specify an FMECA in the statement of work to subs, if any. (4) The contractor will require an FMECA in the data package obtained from the OTS vendors.
Maintainability	1A304	(1) Specify the use of maintainability as one of the design parameters in subsystem modularization studies. Provide the maximum ground storage period expected for the worst case mission.	(1) Contractor to determine: o Storage conditions required for modularized subsystems. o Maximum storage time allowable before degradation begins. o Expected degradation of equipment during long term storage. o Replacement or refurbishment requirements after long term storage. o Replacement or refurbishment required after x missions, where x - 1, 2, 3...n. o Most efficient modularization vs. maintenance requirements by subsystem. o Limiting item list for long term storage or for long term operation.
Design Review Program Program	1A305	(1) Specify design reviews at system level only. * (2) Utilize the final design review to confer or reject qaual. status to components/subsystems. (3) Specify that the final design review will only review changes occuring since last design review. (4) Utilize initial design review to determine where any special testing should be concentrated.	(1) Set up a policy on the design reviews applied to: o off-the-shelf equipment o off-the-shelf modified equipment o new equipment (2) Utilize informal reviews with a NASA QC&R Rep. as a participant to examine component/subsystems. (3) Include maintainability and storage on the agenda. (4) Prior to final design review publish a tabulation of design or other changes occurring since the last review.
Problem, Failure Reporting and Correction	1A306	Part of Quality Plan	
Parts, Devices & Materials Program	1A308	Part of Quality Plan	

Table 4-12. Proposed Reliability Program Provisions (Based on NHB 5300.4 (1A))

The modifications recommended in each of these areas is discussed in detail in the following paragraphs.

Paragraph 1B103 <u>Quality Program Requirements</u>

In addition to the Approval, Review, and Information actions shown, additional category, "Retain in Contractor's File", should be added to the list. Many of the documents shown in Appendix A are not required by NASA to perform their day-to-day duties. It would be cheaper and more efficient to retain them at the Contractor's plant in a file subject to review by NASA.

Paragraph	Document	Recommended Action
1B202-1	Training Document	Retain in Contractor Files
1B202-4	Training and Certification Records	Retain in Contractor Files
1B203	Quality Information	Retain in Contractor Files
1B204	Quality Status Report	Information Copy - as portion of Program Report
1B205-3	Quality Program Audit Reports	Retain in Contractor Files
1B206	Quality Program Plan	Approval Copy
1B206-2b	Policies and Procedures	Retain in Contractor Files
1B300	Technical Documents	Retain in Contractor Files
1B300-2	Document Review	Retain in Contractor Files
1B302	Change Control Systems Document	Approval Copy - Systems Specification, Contract and Statement of Work Changes.
1B404	Identification List	Retain in Contractor Files
1B501-1	Quality Records	Retain in Contractor Files

Paragraph	Document	Recommended Action
1B501-2	Pre-Award Survey Results	Retain in Contractor Files
1B502	Procurement Documents	Retain in Contractor Files
1B506	Receiving Records	Retain in Contractor Files
1B508-1	Post-Award Survey Schedules	Retain in Contractor Files
1B508-1	Post-Award Survey Results	Retain in Contractor Files
1B600	Fabrication Documents	Retain in Contractor Files
1B603-2	Process Control Procedures	Retain in Contractor Files
1B603-3	Equipment Certification Records	Retain in Contractor Files
1B604	Workmanship Standards	Retain in Contractor Files
1B701	Inspection and Test Planning	Retain in Contractor Files
1B702	Test Specifications	Retain in Contractor Files
1B703	Inspection and Test Procedures	Retain in Contractor Files
1B704	End-Item Inspection and Test Specifications and Procedures	Retain in Contractor Files
1B705-7	End-Item Inspection and Test Report	Retain in Contractor Files
1B706-1	Inspection and Test Records and Data	Retain in Contractor Files
1B706-2	Equipment Records	Retain in Contractor Files
1B801	Nonconformance Documentation	Review Copy - functional problems during Subsystem or System level testing. Information Copy - functional problems of component level of test.

Paragraph	Document	Recommended Action
		Retain in Contractor Files - all other anomalies and discrepancies.
1B900	Procedures for Measurement processes	Retain in Contractor Files
1B902-3	Results of Evaluations	Retain in Contractor Files
1B905-7	Calibration Records	Retain in Contractor Files
1B1000	Stamp Control Procedures	Retain in Contractor Files
1B1100-1	Handling Instructions	Retain in Contractor Files
1B1100-2	Storage Procedures	Retain in Contractor Files
1B1101-3	Packaging Procedures and Instructions	Retain in Contractor Files
1B1102-2	Documentation Package	Information Copy - accompany shipment
1B1200	Sampling Plans	Retain in Contractor Files
1B1300-4	Government Property Records	Retain in Contractor Files

Paragraph 1B204
Quality Status Reporting

A separate Quality Status Report would duplicate much of the information included in the Program Status Report. It is recommended that the Quality activities should be included as an integral portion of the Program Report.

Paragraph 1B300
Technical Documents
and
Paragraph 1B302
Change Control

A major cost driver in the Configuration Management area is the requirement for customer approval of lower tier documents and changes thereto. NASA absorbs the high cost impact of this requirement by virtue of the need to assign people to review the documents, raise questions, negotiate, and approve. The contractor suffers schedule delays during this period and his cost goes up accordingly. To minimize these costs on the EOS Program, it is recommended that a minimum list of documents requiring customer approval be drawn up. The list would be restricted to the Contract, System Specification, and Statement of Work. Lower tier documents, such as acceptance test procedures or component specifications, should not require customer approval. It is axiomatic that approval authority for a document does hand-in-hand with change control authority. Thus, changes to these lower tier documents would not require customer approvals unless the change affects the System Specification, Statement of Work or the Contract.

Paragraph 1B502
<u>Procurement Documents</u>
and
Paragraph 1B504
<u>Government Source Inspection</u>

Current NASA space programs include the provision for Government Source Inspection (GSI) imposed upon the spacecraft prime contractor and his subcontractors and suppliers. This requirements includes the provision for a resident government imspector to perform mandatory inspections on the hardware, witness of test, optional or random Product Quality Monitoring activities, and other quality oriented activities. Cost and schedule savings can be achieved on the EOS Program by a reduction in the extent of this source inspection activity, without a concurrent reduction in hardware quality.

Reduction in the GSI inspection and test monitoring function would eliminate the potential multiple inspection coverage at subcontractors and suppliers' plant, where the work is inspected and tests are witnessed by the subcontractor or supplier, by the prime contractor source inspector, and also by the government source inspector. In addition, the possibilities for schedule slips and cost increases resulting from the source inspector not being available when needed would be reduced. The in-series mandatory inspections, performed after the inspection function has been completed by the contractor or supplier, and the test monitoring by the government source inspector should be changed. Instead, the Government source inspector or the NASA Quality Monitor would perform an initial evaluation or survey of the contractor's capability at the beginning of the program. Then he would perform audits of quality activities, rather than full time in-series mandatory inspections and test witnessing.

This reduction in government source inspection on scientific applications spacecraft programs would be appropriate for several reasons:

- The usual concept of GSI is more applicable to high volume production orders. For limited production programs there is little opportunity for the government inspector to become familiar with the program requirements and the hardware to be built for that program, especially for subcontracted items.

- GSI at facilities of small contractors has not been effective because in many cases the inspector has had to split his time between several remote facilities, or between several different programs.

As a result, communications and understanding of program requirements, and the ability of the inspector to keep up to date on day-to-day activities has been difficult. In these circumstances, it is often difficult to get the inspector rapidly when he is needed to perform his mandatory activities, resulting in schedule delays to the hardware in process.

o The government/industry relationship has matured to the point where the Prime Contractor, with ultimate responsibility to ensure hardware quality, is allowed to establish the system to assure that product quality is achieved.

Paragraph 1B801
<u>Nonconformance Documentation</u>

The requirements for formal Nonconformance Reporting at all levels of inspection and test results in an expensive operating system. The resultant large amount of in-process information masks the more significant acceptance test problems, and the formal handling, resolution, and dispositioning procedure can result in significant delays. It is generally believed that an informal method of reporting and handling in-process problems would eliminate these disadvantages and result in reduced costs without reducing the hardware/system quality or reliability. This informal system would be used to handle problems that occur before the initiation of acceptance testing on flight units or qualification testing on prototype units, process fall-out within acceptable limits, structure problems, and harness problems other than those that occur during electrical testing on the Spacecraft. The information on these problems would be entered in a logbook or working file. It would be the responsibility of the cognizant engineers to analyze these problems, establish both the disposition and corrective action to be taken, and coordinate this activity with other interested personnel. The information on both the problems and resultant actions taken would be retained on file for future reference and analysis. It is recommended that the EOS Program requirements allow an informal system of this nature to supplement the formal system of reporting more significant individual problems.

Paragraph 1B804
Material Review Board

The Contractor Material Review Board on the EOS Program should not require a Government representative for the disposition of Class II anomalies (variations). The imposition of the Government representative on the Contractor MRB should be limited to Class I anomalies (deviations) that could have some adverse effect upon the Spacecraft mission. This change would result in a direct saving to NASA by reducing the government workload and an indirect saving through the increased efficiency of effort that could be applied to the disposition and correction of the deviations. In addition, the Contractor could handle the variations more efficiently and expeditiously without affecting the overall EOS Program quality or reliability.

Paragraph 1B806
Supplier Material
eview Board

This paragraph should be amended to allow the Contractor to delegate Class II Material Review Board responsibility to suppliers without NASA approval of each such delegation. Industry's experience with suppliers and major subcontractors has enabled it to adequately judge the ability of each company to perform these activities.

4.7 PROGRAM DOCUMENTATION

A high portion of the cost of data management for a spacecraft system is the cost of documentation delivered to the customer. Frequently the CDRL list provides for submission of data because the data exists in the contractor's facility and it would be "nice to have".

The "business as usual" CDRL has been reviewed with the following thoughts in mind to reduce the EOS CDRL to those documents which are necessary and sufficient for NASA management of the EOS Program.

- o Availability of information at the contractor's facility for customer perusal rather than required submission.
- o Maximum combination of reports to reduce redundant efforts.
- o Use of contractor internal documentation whenever possible.
- o Use of multi-detail drawings.
- o Use of red-line and/or preliminary drawings in development phase.
- o Use of existing NASA approved documents applicable to EOS.
- o Reduce depth and frequency of financial and progress reports.
- o Maximize exception reporting to minimize cyclic reports.
- o Reduce number of copies submitted to essentials.

With the implementation of the above considerations, a sizable cost reduction can be made. GE has developed a recommended EOS CDRL, as shown in Table 4-13, which consists of 41 items. This was developed by deleting items from the extensive 211 item CDRL of a previous NASA/GE program.

4.8 DESIGN-TO-COST

The greatest single difference between a spacecraft and commercial products development and fabrication program is relative unit cost (granted that such a comparative cost is difficult at best to achieve). That this difference exists is not surprising considering that

Table 4-13. Recommended CDRL For EOS-A

1.	Configuration Criteria Document	Once
2.	Mass Properties Status	Once
3.	Interface Definition Document	Once
4.	Configured Article List	Once
5.	New Technology Report	Annual
6.	Program Schedule and Status Report	Bi-Monthly
7.	EOS Safety Plan	Once
8.	Financial Report	Quarterly
9.	Data User's Handbook	Once
10.	Contract Work Breakdwon Structure	Once
11.	Electrical System Schematic	Once
12.	Spacecraft Integration and Test Procedures and Requirements	Once
13.	Pre-Launch Procedures and Requirements	Once
14.	AGE Procedures and Checkout Requirements	Once
15.	General Purpose S/C Integration and Test Requirements	Once
16.	Data Processing Subsystem Integration Procedures	Once
17.	Bench Integration Test Procedures and Requirements	Once
18.	Thermal Control Requirements	Once
19.	Observatory Acceptance Test Reports	Elect. Sys. T/V After Launch
20.	Data Processing S/S Integration Test Report	Once

Table 4-13. Recommended CDRL For EOS-A
(Continued)

21.	Reliability Program Plan	Once
22.	Quality Assurance Program Plan	Once
23.	Malfunction Reports	As Required
24.	Failure Analysis Reports	As Required
25.	Material Inspection and Receiving Report	At Delivery
26.	Shuttle Compatibility Plan	Once
27.	S/C Autonomy Plan	Once
28.	S/C System Specifications	Once
29.	Basic Software Specifications	Once
30.	Interface Specifications	Once
31.	Thematic Mapper Specifications	Once
32.	HRPI Specifications	Once
33.	Attitude Control S/S Specifications	Once
34.	Power S/S Specifications	Once
35.	Communication and Data Handling Specifications	Once
36.	Data Collection System Specifications	Once
37.	Mission/Systems Specifications	Once
38.	Ground Systems Specifications	Once
39.	Initial Activation Document	Once
40.	Flight Evaluation Report	After Launch Quarterly
41.	Type III Final Report	On Vehicle Delivery

in the Aerospace industry, performance comes first with cost second; whereas performance is secondary to cost for a commercial product. The method of keeping the cost low in commercial enterprises is "Design-To-Cost" which is an iterative process whereby hardware and services are provided within the total cost constraints established by the customer or market. In the simplest sense, the price which the market or consumer is willing to pay for the product dictates what the selling price will be. Performance, reliability, and quality are traded down to meet the cost goal. The process is actively applied throughout the conceptual design, tooling, procurement, production phases of a product cycle to provide a positive means of meeting overall product cost requirements. This is accomplished by establishing a total project cost target, breaking down the total target to lower level targets all the way to individual component parts, assigning responsibility for meeting each cost target, monitoring performance throughout the design, test, tooling, procurement, and production phases; identifying variances, and taking corrective action. The process involves the identification of required functions and the application of creative techniques to develop minimum cost means of providing those functions. In this manner total cost becomes an input to the design process rather than a result of it.

Historically, the Aerospace industry has not been asked to take a "commercial product" approach to spacecraft design and fabrication. Rather, industry has been asked to provide technologically advanced products of an extremely high reliability with cost very subservient to performance to minimize the risk of failure. This was rightly so since once launched the spacecraft is no longer accessible for repair or maintenance. The failure of a commercial product merely means a trip to the repair shop of which there are none yet in space.

With the advent of the space shuttle, perhaps spacecraft are now ready for a design to cost approach since they will be accessible for repair, maintenance and return to the shop.

To apply design to cost in a spacecraft program like EOS appears feasible provided that NASA plans a two-step procurement, a design to cost phase and an implementation phase. During the design phase:

- o Required performance envelopes are defined;
- o Performance characteristics and levels which influence fabrication, test, launch and operations costs are determined;
- o Design configurations are costed on a life cycle basis; and
- o Realistic cost goals are established as a function of performance.

Then as a result of the Design-To-Cost phase, the design implementation phase of the contract is consumated at the cost goals established by NASA and Industry. This two-step procurement is not unlike the practice of competitive design contract followed by a production contract. What is new is that NASA and Industry would jointly select modification of those performance parameters which can reasonably be accepted prior to and during the shuttle era so as to minimize the spacecraft life cycle cost.

4.9 VALUE MANAGEMENT

The basic principles and techniques involved in "Value Management" were initially developed by General Electric nearly thirty years ago, and have been very successfully practiced by many companies all over the world. They involve the development of creative, innovative thought. The principles have also been effectively practiced by a number of government agencies for twenty years. The Department of Defense alone has realized savings in the hundreds of millions of dollars in cost elimination during this period of Value Improvement. Other agencies, such as the Department of Transportation and the General Services Administration are currently employing contract provisions for the effective management of Value by their contractors.

When specific low cost goals are established, the proper application of Value Management techniques can generally enable the contractor to meet the goals, provided there is timely authorization for the Value Engineering work, and provided that it is conducted by experienced, knowledgeable practioners, with full government cooperation and assistance.

Most high technology programs are managed in an environment of "performance emphasis", on a cost reimburseable basis that provides protection when overruns are encountered. Priorities are generally assigned to elements of the program without challenging the overall value of the element, or the value of the specific components of the element. Consequently, costs tend to grow as "necessary" to the proliferation of requirements for performance, reliability, schedule, and risk. As long as there are appropriations sufficient to cover the costs, the relative importance of holding down costs is secondary to these other program parameters.

The term "Low Cost" is often used to convey a basic desire that really includes other factors. Naturally, no one wants low cost at the expense of the ability of the EOS to effectively perform the needed functions with the necessary reliability. Moreover, no one wants the low cost to justify increasingly high risk schedule slippage. The interrelationship of these factors can be expressed as the VALUE of the EOS, where:

$$\text{VALUE} = \frac{\text{NEED x PERFORMANCE x RELIABILITY}}{\text{COST x RISK x SCHEDULE}}$$

In offering a Value technique for "Low Cost Management" therefore, an appropriate term, based on the formula for value, is "Value Management". This section is addressed to a method of assuring a lower cost program, without sacrificing any other necessary characteristics, through a program of "Value Management" that will minimize the cost without impairing the capability of the EOS to fulfill its mission.

Other cost trade studies of Value Management have indicated a significant reduction in proposed program costs by initiating this technique as early as possible (even as early as the RFP response). Therefore, based upon the contracting technique recommended earlier (namely, phased contracts for the Prime Contractor) initiation of Value Management in Phase I seems a natural for causing lower cost designs than might occur without the application of this technique.

Value management may be applied either by use of the "Program Clause" or the "Incentive Clause".

The "Program Clause" provides for funding at a specified level for value investigations. These "Program Clauses" generally are applicable to Design and Development contracts, and they ensure that the Value Engineering work is indeed accomplished. They generally provide for a modest (10% to 25%) sharing of savings with the contractor as an incentive. Experience shows that the application of this "Program Clause", which institutes Value Engineering in the design phase, has a greater cost savings than if Value Engineering changes are made at a later phase of the program. In other words, it is less costly to design it right the first time by Value Engineering techniques, than it is to retrofit.

The "Incentive Clause" authorizes the expenditure of contractor's funds (indirect) for "Value Management". Incentive to perform takes the form of increased percentages of "sharing" in the cost reductions identified and accepted by contract changes. The sharing incentive can be, for example, 50% to the government, and 50% to the contractor, depending on the type of contract. It can also be extended to subcontractors. It is particularly appropriate in production contracts, where large multipliers exist with large quantity, but it is also quite successful, when applied to development contracts, and to single quantity projects as well.

For the EOS Program, it is recommended that NASA incorporate a "Program Clause" for Value Management, providing for $100,000 of specific effort. It is also recommended that NASA contribute to the selection of the two to four studies to which this funding should be allocated. It has been established that the early application of the technique will provide the greatest cost saving impact on the program. If, for example, the twenty to one return is realized on the EOS Program, it would not be unreasonable to identify $2,000,000 for removal, where discrete courses of action are changed. If, however, the Value Engineering is conducted at the very outset of a program, it will ideally provide the direction needed before establishing any design to be changed.